U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 103.

L. O. HOWARD, Entomologist and Chief of Bureau.

THE PLUM CURCULIO.

BY

A. L. QUAINTANCE,

In Charge of Deciduous Fruit Insect Investigations,

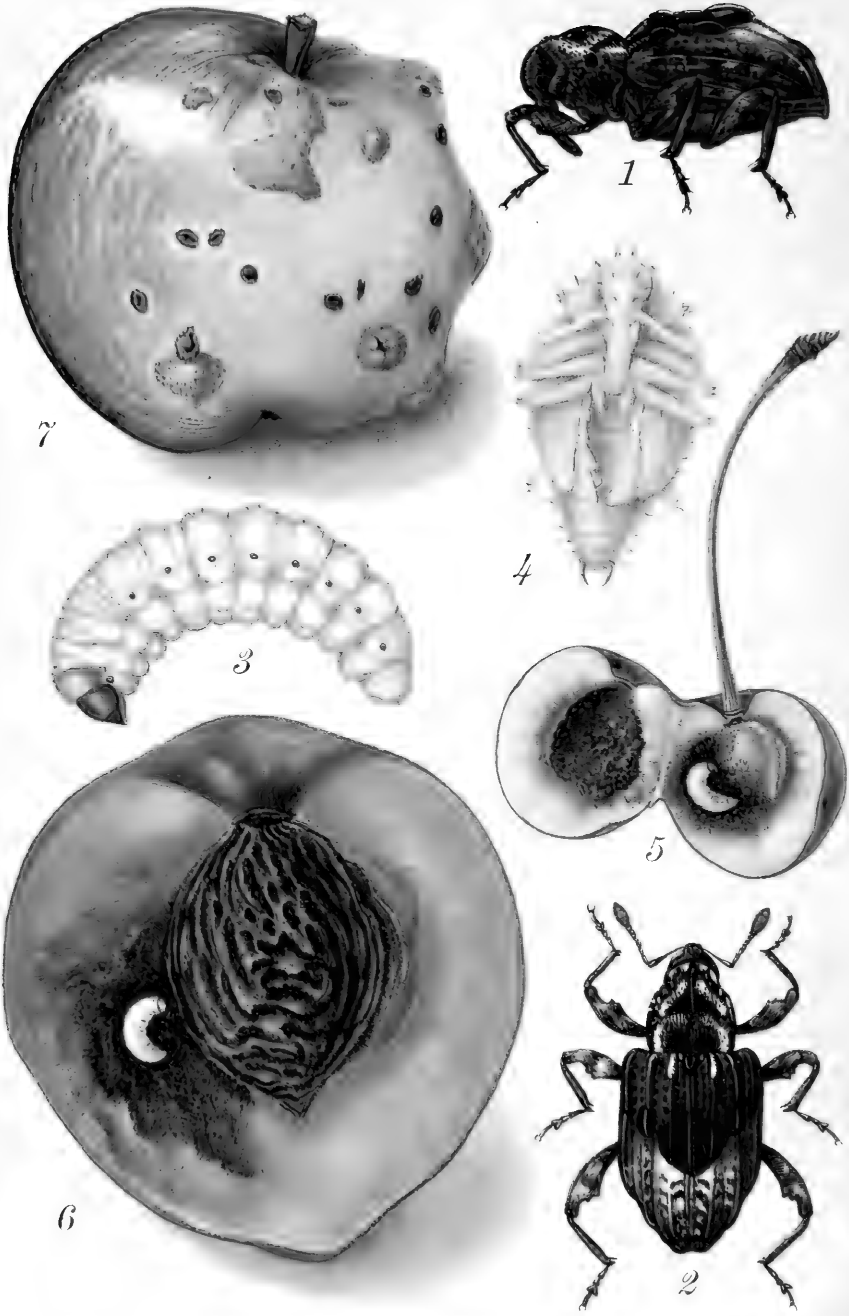
AND

E. L. JENNE,

Agent and Expert, Deciduous Fruit Insect Investigations.

ISSUED JULY 13, 1912.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1912.



STAGES AND WORK OF THE PLUM CURCULIO.

Fig. 1, The adult or beetle, lateral aspect; fig. 2, beetle, dorsal aspect; fig. 3, larva, or grub, lateral aspect; fig. 4, pupa, ventral aspect; fig. 5, larva, and its work in cherry; fig. 6, injury to ripe peach; fig. 7, feeding punctures and scars from egg punctures on apple. Figs. 1-4, enlarged about 8 times; Figs. 5-7, natural size. (Original.)

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 103.
L. O. HOWARD, Entomologist and Chief of Bureau.

THE PLUM CURCULIO.

BY

A. L. QUAINTANCE,
In Charge of Deciduous Fruit Insect Investigations,

AND

E. L. JENNE,
Agent and Expert, Deciduous Fruit Insect Investigations.

Issued July 13, 1912.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1912.

BUREAU OF ENTOMOLOGY.

L. O. Howard, *Entomologist and Chief of Bureau.*
C. L. Marlatt, *Entomologist and Acting Chief in Absence of Chief.*
R. S. Clifton, *Executive Assistant.*
W. F. Tastet, *Chief Clerk.*

F. H. Chittenden, *in charge of truck crop and stored product insect investigations.*
A. D. Hopkins, *in charge of forest insect investigations.*
W. D. Hunter, *in charge of southern field crop insect investigations.*
F. M. Webster, *in charge of cereal and forage insect investigations.*
A. L. Quaintance, *in charge of deciduous fruit insect investigations.*
E. F. Phillips, *in charge of bee culture.*
D. M. Rogers, *in charge of preventing spread of moths, field work.*
Rolla P. Currie, *in charge of editorial work.*
Mabel Colcord, *in charge of library.*

Deciduous Fruit Insect Investigations.

A. L. Quaintance, *in charge.*

Fred Johnson, E. L. Jenne, S. W. Foster, P. R. Jones, F. E. Brooks, A. G. Hammar, E. W. Scott, R. L. Nougaret, R. A. Cushman, L. L. Scott, J. B. Gill, A. C. Baker, W. M. Davidson, E. B. Blakeslee, W. B. Wood, E. H. Siegler, F. L. Simanton, *entomological assistants.*

J. F. Zimmer, N. S. Abbott, W. H. Sill, *entomological assistants, employed in enforcement of insecticide act, 1910.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., October 24, 1911.

Sir: I have the honor to transmit herewith for publication a full account of the plum curculio. This is a native insect, and from the earliest times has ravaged the plums, peaches, and other deciduous fruits grown around the home and in large commercial orchards. The total annual loss occasioned by this pest by reason of its attacks upon its several food plants amounts to several million dollars, and until recently there has been no very practical method of controlling it.

The plum curculio has been under careful investigation by this bureau during the past several years, and, although it has been the subject of many papers by entomologists and others, it has not heretofore received the painstaking investigation which its importance demands. The present paper is an important contribution to our knowledge of the insect, and points out the remedial measures to be employed in its control.

I recommend the publication of this manuscript as Bulletin No. 103 of this bureau.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The present bulletin gives results of studies of the plum curculio that, with considerable interruption, have been in progress since the spring of 1905. The work has been done for the most part in conjunction with other investigations at the field laboratories in Deciduous Fruit Insect Investigations, Bureau of Entomology, located in important fruit-growing sections and representing a considerable range of climatic and other conditions. Data have thus been obtained on the biology of the insect in northern, central, and southern localities in its range of distribution, as in western New York and northwestern Pennsylvania, in the environs of Washington, D. C., and in Georgia. Studies for one season were made in the Ozark region of Arkansas, well toward its limit of occurrence to the southwest. The observations presented, therefore, fairly well cover the distribution of the species, though for the respective localities the results are not entirely comparable, as for one reason or another it was found impractical for the several workers to carry out uniformly the outline of studies originally prepared.

In the case of but few native American insects are there earlier or more complete records of depredations than is true of the plum curculio. From the time of its first noted injuries, about 175 years ago, until the present day this insect has been execrated by commercial and amateur fruit growers alike. If we are to judge from the writings in the earlier horticultural and agricultural papers, it was especially despised by the early settlers for its destruction of choice varieties of plums and other stone fruits grown around their homes, and the number of remedies proposed was legion. Many workers have contributed to our present knowledge of the plum curculio, and their writings have been freely used in the present paper. Among these may be mentioned Fitch, Walsh, Riley, Trimble, Forbes, Howard, Weed, Stedman, Crandall, and others.

Several members of the force engaged in Deciduous Fruit Insect Investigations have made important contributions to this report, as later credited in the text. Mr. James H. Beattie spent a part of the season of 1905 in Georgia, and Mr. A. A. Girault during the same year was engaged in life-history observations in the insectary at Washington. During 1906 Mr. Girault, with Mr. A. H. Rosenfeld, spent the season in Georgia working on the curculio and other peach insects, and the year following the former gentleman made observations on this insect in southern Ohio. Mr. Girault's careful studies have been of the greatest value. During 1905 Mr. Fred Johnson gave considerable

attention to life-history studies of the curculio in western New York, as also the year following in northwestern Pennsylvania, in addition to numerous field experiments in spraying during these and subsequent years. During 1908 Mr. S. W. Foster and the junior author carried out extensive life-history investigations and field experiments in northwestern Arkansas, and similar work was accomplished the same season in the environs of Washington, D. C., by Mr. P. R. Jones. During 1909 work on the curculio was limited largely to experiments with sprays in orchards, made in conjunction with experiments against the codling moth, and carried out in Arkansas and Missouri by the junior author and Mr. F. W. Faurot, in Virginia by Messrs. J. F. Zimmer and E. W. Scott, and in Michigan by Mr. R. W. Braucher. In 1910 important life-history observations were made in Michigan by Mr. A. G. Hammar, and many additional data on the curculio in the South were obtained during the same year by the junior author and Mr. E. W. Scott, with headquarters at Barnesville, Ga. In much of the orchard-spraying experiments on both peach and apple the work has been done in cooperation with Mr. W. M. Scott, of the Bureau of Plant Industry of this department.

Several publications on the plum curculio have been issued during the course of the work. An article on this insect was published in the Yearbook of the department for 1905 in a paper entitled "The principal insect enemies of the peach." Circular 73 of the Bureau of Entomology, on the plum curculio, by Messrs. Fred Johnson and A. A. Girault, was published in 1906; and the results of a comparison of the demonstration and one-spray methods in the control of the codling moth and plum curculio were published in November, 1910, as Part VII of Bulletin No. 80 of the Bureau of Entomology, a revised edition of which was issued March 30, 1911. Circular 120 of the Bureau of Entomology, entitled "Control of the Brown-rot and Plum Curculio on Peaches," by W. M. Scott, of the Bureau of Plant Industry, and the senior author, was issued in March, 1910. This gave instructions for the preparation and use of a combined spray for the curculio and fungous diseases of the fruit of the peach. The results of further experiments in peach spraying for the curculio, brown-rot, and scab were given in Farmers' Bulletin 440, by W. M. Scott and the senior author, published in March, 1911.

In the present paper are brought together the more detailed results of the studies of this insect which have been in progress, including some of the data which have been already published. Especial attention has been given to presenting the data as far as possible in tabular form, with necessary discussion of the tables to bring out the more important points.

A. L. Quaintance,
In Charge of Deciduous Fruit Insect Investigations.

CONTENTS.

	Page.
Classification and synonymy	13
Common names	14
History	15
Distribution	19
Western limit of occurrence	21
Northern limit of occurrence	24
Southern limit of occurrence	25
Distribution of the curculio according to life zones	25
Reported introductions of the curculio	26
Losses due to the plum curculio	27
Insects likely to be mistaken for the plum curculio	28
Description	30
The egg	30
The larva	30
The pupa	32
The adult	33
Food plants	33
Fruits in which the larvæ fail to mature	38
Life history and habits	39
The egg	39
Number of eggs deposited	39
Length of egg stage	48
The larva	54
Habits of larvæ just hatched and course taken in fruit	54
Larval instars	55
Death of larvæ in fruit	56
Desertion of fruit by undersized larvæ	59
Normal emergence of larvæ from fruit during the season	60
Manner of leaving the fruit and entering soil	64
Time spent in the fruit (egg and larval stages combined)	65
The pupa	73
Length of time spent in the soil	73
Length of pupal stage, and time spent in soil before and after pupation	83
Depth of pupal cell	87
Soil conditions affecting transformations of the curculio in the ground	88
The adult	92
Period of emergence of beetles	92
Proportion of sexes	95
Choice of food by curculio	96
Extent of feeding of the respective sexes	98
Operation of egg laying	99
Egg and feeding punctures: Position on fruit and variation in form	103
Relative number of feeding and egg punctures	106
Activity of the beetles in egg laying and feeding, by day and by night	107
Time required for transformation from egg to adult	110

	Page.
Seasonal history	112
Time of appearance of beetles in spring	112
Relation of temperature to appearance of beetles	118
Occurrence of beetles in orchards	120
Number of generations annually	125
Beetles from emergence to hibernation	127
Hibernation	129
Mortality of the curculio during hibernation	132
Percentage of fruit punctured or infested by the plum curculio	134
Natural enemies	139
Parasitic insects	140
(*Anaphes*) *Anaphoidea conotracheli* Girault	140
(*Sigalphus*) *Triaspis curculionis* Fitch	142
(*Sigalphus*) *Triaspis curculionis* var. *rufus* Riley	146
(*Porizon*) *Thersilochus conotracheli* Riley	147
(*Bracon*) *Microbracon mellitor* Say	148
Bracon dorsata Say	148
Other hymenopterous parasites	148
Myiophasia ænea Wiedemann	149
Cholomyia inæquipes Bigot	150
Pegomya fusciceps Zett	151
Predaceous insects	152
Fowls and birds as curculio destroyers	154
Remedial measures	155
Historical	155
Premiums for remedies for the curculio	167
The Ransom chip process	168
Jarring for the curculio	168
Present status of jarring	172
Cultivation for destruction of pupæ	176
Spraying with arsenicals	178
Feeding experiments with poisons	185
Spraying for the curculio on apple	189
Early experiments	189
Experiments by the Bureau of Entomology	193
Experiments at Anderson, Mo	193
Experiments in western New York and northwestern Pennsylvania	195
Experiments at Siloam Springs, Ark	196
Experiments in Virginia	197
Experiments at St. Joseph, Mo	198
Conclusions	200
Scheme for spraying apple orchards	201
Spraying peaches with arsenicals	202
Some results of spraying peaches for the curculio	208
Directions for the preparation of self-boiled lime-sulphur wash	212
Directions for using arsenate of lead	213
Schedule of applications	214
Midseason varieties	214
Late varieties	214
Early varieties	214
Spraying plums and cherries	215
Some results of spraying plums	216
Results of spraying cherries	218
Economic bibliography	219
Index	243

ILLUSTRATIONS.

PLATES.

		Page.
Plate I.	Stages and work of the plum curculio. Fig. 1.—The adult or beetle, lateral aspect. Fig. 2.—Beetle, dorsal aspect. Fig. 3.—Larva. Fig. 4.—Pupa. Fig. 5.—Larva, or grub, and its work in cherry. Fig. 6.—Injury to ripe peach. Fig. 7.—Feeding punctures and scars from egg punctures on apple	Frontispiece.
II.	Work of plum curculio on plum. Fig. 1.—Egg and feeding punctures on young wild-goose plum. Fig. 2.—Nearly ripe wild plums, showing egg scars and gum exudation from feeding punctures	32
III.	Work of plum curculio on plum. Fig. 1.—Effect of egg and feeding punctures, with gum exudations, on ripe Japanese plums. Fig. 2.—Fall feeding punctures on ripe prunes	32
IV.	Work of plum curculio on peach. Fig. 1.—The adult curculio on newly set peach. Fig. 2.—Curculio larva, or grub, and its work in ripe peach	36
V.	Work of plum curculio on peach. Fig. 1.—Wormy windfall peaches. Fig. 2.—Peaches deformed by egg and feeding punctures	36
VI.	Work of plum curculio on peach. Fig. 1.—Deformed ripe peaches. Fig. 2.—Gum exudation from curculio punctures	36
VII.	Work of plum curculio on apple. Fig. 1.—Egg and feeding punctures on young apples. Fig. 2.—Egg punctures on apple some days old	40
VIII.	Work of plum curculio on apple. Fig. 1.—Young apples, showing scars from egg punctures. Fig. 2.—Ripe apples deformed and knotty from egg and feeding punctures of the curculio	40
IX.	Work of plum curculio on apple. Fig. 1.—Imperfectly developed apple from tree in which curculio grubs matured. Fig. 2.—Small drop apples in which curculio grubs matured. Fig. 3.—Nearly ripe summer apple from ground, showing extent of feeding by two curculio larvæ	40
X.	Injury by plum curculio to pears. Knotty and deformed ripe pears resulting from egg and feeding punctures	44
XI.	Plum curculio injury to cherries. Cherries cut open, showing the grub and its work	44
XII.	Methods of study in plum-curculio investigation, Barnesville, Ga. Fig. 1.—Out-of-door house used in life-history work. Fig. 2.—Soil cages used in obtaining data on life of insect in ground	48
XIII.	The fall feeding punctures of the plum curculio on apple. Fig. 1.—Characteristic holes eaten into apple by the beetles in the fall. Fig. 2.—Feeding punctures of beetles on summer apples	128
XIV.	Jarring apparatus in use or recently in use against the plum curculio. Fig. 1.—A wheelbarrow curculio catcher used in New York State. Fig. 2.—Curculio catcher made by sheets on frames, in use a few years ago in Georgia	172

Page.

PLATE XV. Benefits of spraying apples for the plum curculio. Fig. 1.—Duchess apples from trees in unsprayed plat. Fig. 2.—Duchess apples from trees in plat sprayed against the plum curculio with arsenate of lead ... 196

XVI. Conditions favoring the plum curculio. Fig. 1.—Native plum thicket in the south, adjacent to peach orchard. Fig. 2.—Woods and thicket adjacent to plum orchard, furnishing the beetles with excellent hibernation quarters ... 200

XVII. Effect of arsenical sprays on peach foilage, Arlington Farm, Va. Fig. 1.—Unsprayed or check tree. Fig. 2.—Tree sprayed once with commercial arsenate of lead. Fig. 3.—Tree sprayed once with homemade arsenate of lead. Fig. 4.—Tree sprayed once with Paris green. Fig. 5.—Tree sprayed once with green arsenoid. Fig. 6.—Tree sprayed once with arsenic sulphid ... 208

XVIII. Arsenical injury to fruit. Fig. 1.—Elberta peach sprayed three times with arsenate of lead, showing burning and cracking effect of the poison. Fig. 2.—Japanese plums, showing burning from one application of arsenate of lead ... 208

XIX. Field experiments in Georgia for control of plum curculio and peach diseases. Fig. 1.—Gasoline power outfit in operation. Fig. 2.—Determining results of spraying, each peach being cut open ... 212

XX. Size of peaches at time of first spraying with arsenate of lead, showing on the left the earliest and on the right the latest stages in development when this treatment should be given ... 214

TEXT FIGURES.

FIG. 1. Herbst's figure of plum curculio, accompanying the original description in 1797 ... 16
2. An early illustration of the plum curculio, frequently used between about 1830 and 1850 ... 17
3. Peck's figure of the plum curculio, published with his description (*Rhynchænus cerasi*) in 1819 ... 17
4. Map showing by the shaded area the distribution of the plum curculio ... 25
5. The apple curculio (*Anthonomus quadrigibbus*) ... 28
6. The plum gouger (*Anthonomus scutellaris*) ... 28
7. The acorn weevil (*Balaninus victoriensis*) ... 29
8. Fuller's rose beetle (*Pantomorus fulleri*) ... 29
9. Imbricated snout beetle (*Epicærus imbricatus*) ... 29
10. The plum curculio (*Conotrachelus nenuphar*): Egg ... 30
11. The plum curculio: Larva, showing structural details ... 30
12. The plum curculio: Head of larva, with parts named ... 31
13. The plum curculio: Head of larva, lateral aspect, with parts named ... 31
14. The plum curculio: Head of larva, ventral aspect, with parts named ... 31
15. The plum curculio: Lateral, dorsal, and ventral aspects of right mandible of larva, with muscles ... 31
16. The plum curculio: Dorsal aspect of maxilla and labium of larva, with parts named ... 32
17. The plum curculio: Pupa, showing structural details ... 32
18. The plum curculio: Mouth parts of the adult ... 33
19. Black-knot of plum, showing, on the left, infestation by plum-curculio larvæ ... 37

Page.

FIG. 20. Diagram showing normal emergence from fruit of larvæ of plum curculio during season at Siloam Springs, Ark., Barnesville, Ga., Washington, D. C., and Douglas, Mich 61
21. Diagram showing normal emergence from soil of beetles of the plum curculio for the season at Barnesville, Ga 94
22. Diagram showing normal emergence from soil of beetles of the plum curculio for the season at Siloam Springs, Ark 94
23. The normal plum-curculio egg puncture and egg 105
24. Diagram of portion of peach orchard used in jarring experiments against the plum curculio, Barnesville, Ga., 1910 122
25. (*Anaphes*) *Anaphoidea conotracheli*, an egg parasite of the plum curculio 140
26. (*Sigalphus*) *Triaspis curculionis*, an important parasite of the plum curculio 142
27. (*Porizon*) *Thersilochus conotracheli*, parasitic upon the plum curculio . 147
28. (*Bracon*) *Microbracon mellitor*, an occasional parasite of the plum curculio 148
29. *Myiophasia ænea*, a dipterous plum-curculio parasite: Male and head of female 149
30. *Cholomyia inæquipes*, a fly reared abundantly from the plum curculio at Barnesville, Ga.: Adult, puparium in curculio larval skin. 151
31. *Chrysopa oculata* 153
32. *Harpalus pennsylvanicus*, a ground beetle predatory upon the plum curculio 153
33. *Chauliognathus pennsylvanicus* 154
34. A simple form of curculio catcher for use by one person 170
35. A cumbersome wheelbarrow type of curculio catcher developed and patented about 1869 171
36. A light wheelbarrow curculio catcher for sale as late as 1905 171

THE PLUM CURCULIO.

CLASSIFICATION AND SYNONYMY.

The Rhynchophora, or snout beetles, to which suborder the plum curculio belongs, constitute a very large and important group of coleopterous insects, comprising some of our worst insect pests, as the cotton-boll weevil, grain and rice weevils, nut weevils, plum gouger, strawberry weevil, etc.

The genus Conotrachelus is distinctly American. Le Conte and Horn, in the Rhynchophora of North America, published in 1876, list for this genus 26 species from America north of Mexico. There are, however, many representatives of the genus, the species being especially abundant in the Tropics. Champion, in Volume IV, part 4, of the Coleoptera of the Biologia Centrali Americana, has listed 188 species, and states that about 200 have been described (1906).

The plum curculio was first characterized and named in 1797 by Herbst in his "Natursystem aller bekannten in- und ausländischen Insekten-Käfer" and figured under the name *Curculio nenuphar*, the original description being as follows:[1]

587. Curculio Nenuphar.

Neun und neunzigste Tafel. Fig. 8. H.

Mus. *Herschel.* Curc. longirostris fusco griseoque variegatus, inaequalis, thorace punctis duobus elevatis nigris, elytris lineis elevatis interruptis, dorso gibber carinatus.

Der Käfer ist ohngefähr drittehalb Linien lang, braun und greisscheckig, die Oberfläche sehr uneben. Der Rüssel ist fast länger, als der Brustschild, ziemlich dick, rund, gekrümmt braun und greisscheckig, am Ende schwarz, auf dem Rücken eine feine erhöhete Linie. Die

[1] From the collection Herschel. A long-snouted curculio, varied with brown and gray, unequal; thorax with two elevated black punctures, the elytra with elevated, interrupted lines; the back gibbous and carinate.

The beetle is about 3½ lines long, varied with brown and gray, the surface very uneven. The beak is almost longer than the thorax, moderately thick, round, curved, varied with brown and gray, black at tip, on the upper side with a fine elevated line. The eyes are black and are not prominent; the antennæ are brown. The thorax is varied with brown and gray, on the dorsal surface a very fine, elevated line, on each side of which is anteriorly a large, elevated black dot, and a smaller one posteriorly; these smaller ones a little closer to the median line. The scutellum is depressed. The elytra are varied with brown and gray and possess elevated and always interrupted lines; some of these are more elevated, others less, one at the middle near the suture is much more strongly elevated than the others and forms a large, black, elevated, acutely cariniform tubercle; more toward the tip but also near the suture is again a strongly elevated, abrupt line, the second in size but not equal to that on the dorsum. The legs are also varied with brown and gray, the coxæ are two-toothed.

The home is North America.

Augen sind schwarz, und stehen nicht vor; die Fühlhörner sind braun. Der Brustschild ist braun und greisscheckig, auf dem Rücken ist eine sehr feine erhöhete Linie, an jeder Seite derselben steht nach vorne zu ein großer erhöheter schwarzer Punkt, und ein kleinerer nach hinten zu, die kleineren stehen etwas dichter an der Mittellinie. Das Schildlein liegt tief. Die Deckschilde sind braun und greisscheckig, und haben erhöhete stets abgebrochene Linien, einige erhöhen sich mehr, andre weniger, eine auf der Mitte neben der Nath erhöhet sich weit stärker, als die übrigen, und wird ein großer schwarzer, länglicher, scharf, kielförmig erhöheter Höcker; mehr nach der Spitze zu auch neben der Nath steht wieder eine stark erhöhete abgebrochene Linie, die zweyte am Rang, aber nicht der auf dem Rücken gleich. Die Füße sind auch braun und greisscheckig, die Hüften zweymal gedornt.

Das Vaterland ist Nordamerika.

In 1802 the insect was redescribed by Fabricius in Systema Eleutheratorum under the name *Rhynchænus argula;* in his catalogue of the Insects of Pennsylvania, published in 1806, Rev. F. V. Melsheimer used for the plum curculio the name *Curculio persicæ;* and in 1819 Peck in the Massachusetts Agricultural Repository and Journal named the species *Rhynchænus cerasi.* Dejean lists the curculio in his Catalogue des Coléoptères, published in 1833, as *Conotrachelus variegatus,* and in Sturm's Catalogue (1843) it is given as *Conotrachelus gibbosus* Melsheimer.

The generic position of the insect has been changed from time to time according to the ideas of different writers. Our species appears first to have been referred to Conotrachelus in 1837 by Schoenherr in his Genera et Species Curculionidum under Fabricius's name *argula.* This genus, accredited by some writers to Latreille, was fully characterized by Schoenherr, who is cited by Le Conte and Horn and by other systematists as author of the genus. In Say's Entomology of North America, published in 1831, the name *Cryptorhyncus argula* is used.

The present synonymy of the species is therefore as follows:

1797. *Curculio nenuphar* Herbst, Käfer, Natursystem aller Insekten, VII, p. 29, Tafeln, 99, f. 8, H.

1801. *Rhynchænus argula* Fabricius, Systema Eleutheratorum, II, p. 467.

1806. *Curculio persicæ* Melsheimer, Catalogue of the Insects of Pennsylvania (No. 589), p. 28.

1819. *Rhynchænus cerasi* Peck, Mass. Agric. Repos. and Journ., V, p. 312.

1831. *Chryptorhynchus argula* Say (Descr. N. Am. Curculionides), Ent. North America, I, p. 285 (1859).

1833. *Conotrachelus variegatus* Dejean, Cat. des Coléoptères, 2d ed., p. 297; 3d ed., p. 321; lists as *variegatus.*

1843. *Conotrachelus gibbosus* Melsheimer, Sturm's Catalogue, p. 222.

COMMON NAMES.

The plum curculio has been referred to in literature under many common names, as the fruit curculio, curculio, cherry weevil, peach weevil, peach curculio, peach worm, plum curculio, nenuphar, little Turk, Turk, kerkelo, little joker, etc. Simply "curculio" or "fruit curculio" was employed in many of the earlier articles, though "plum weevil" is also frequently to be noted. The word curculio is of

Latin origin. It was used by Cato in *De Re Rustica* (p. 92), 201 B. C., and other writings; also by Palladius, A. D. 210; by Pliny; and by other Roman authors. It is the name of a well-known comedy of Plautus. In its Latin signification the curculio means a cornworm or weevil, and probably for this reason the name was adopted by Linnæus in his Systema Naturæ, as the genus for a large and diverse assemblage of species of snout beetles. While the Linnæan genus Curculio has long since fallen into disuse by entomologists, the various species having been distributed into other genera, the word is retained in the English vocabulary and applied with qualifying adjectives as the common names of several species of snout beetles, e. g., the plum curculio, rhubarb curculio, poplar curculio, willow curculio, etc. As between the numerous common names applied to the insect under consideration, plum curculio has perhaps become most firmly established from frequent use in the economic literature of the past 20 or 25 years, and the name has recently been adopted by the American Association of Economic Entomologists. It is nevertheless misleading since, while partial to plums, the curculio also injures numerous other fruits. In fact its omnivorous habits as regards stone and pome fruits make it unique among a group of weevils which as a rule confine themselves to one or but few food plants.

HISTORY.

Few American insects have been more written about than the plum curculio. The earliest statement referring to this insect which we have seen is in a letter from Peter Collinson to John Bartram, evidently in response to a complaint by Bartram in an earlier communication. Under date of February 3, 1736, Collinson wrote: "I never heard it was insects that annoyed your plums, apricots, and nectarines. If they are, water that has tobacco leaves soaked in it will kill them by making a basin around the trees, watering them frequently with the water." This reference considered alone might appear to refer to the peach-tree borer. Subsequent correspondence, however, between Bartram and Collinson, cited under history of remedies (p. 156), indicates that probably the curculio was the insect referred to. There are, later, undoubted references to this insect in the correspondence between these two gentlemen, which are quoted on page 156. It would appear that the curculio had become quite troublesome, at least in the environs of Philadelphia, before 1750.

A note by the Swedish naturalist, Peter Kalm, under date of May 18, 1749, and quoted in the bibliography, leaves no doubt of the prevalence of the species in the territory about which he was writing, namely, New Jersey. The original description of this species by Herbst in 1797 indicates that by that time the insect had found its

way into European collections. Benjamin Smith Barton, writing in 1802, states: "The unripe fruit of the peach is greatly injured by the curculio, but the insects most pernicious to the trees are two lepidopterous insects of the genus Zygæna of Fabricius. These, while in the larval state, destroy the bark of the root."

An extended account of the curculio by Dr. James Tilton was published in Willisch's Domestic Encyclopædia in 1804. A considerable knowledge of the insect is shown at this early period and the article was much quoted by subsequent writers for several years. With the increase in the number of journals and papers devoted to horticulture and agriculture, references to the curculio were much more frequent. During the first 30 years of the nineteenth century numerous short articles and notes appeared, the following being among the more important contributors: Dr. James Tilton, J. E. Muse, James Thacher, S. L. Mitchell, William Prince, William

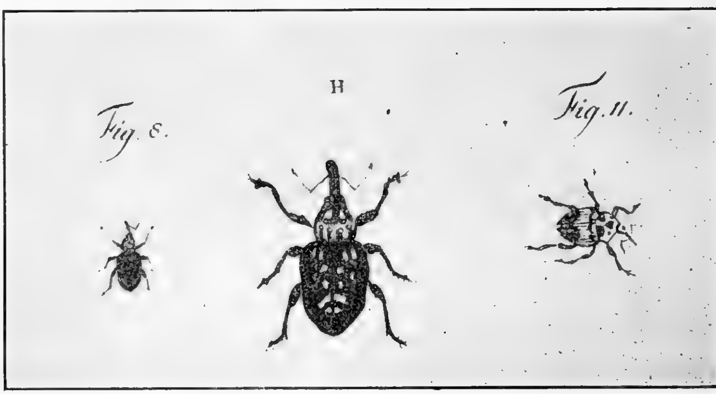


FIG. 1.—Herbst's figure of the plum curculio; accompanying the original description in 1797.

Wilson, and W. D. Peck. (See figs. 1 and 2 for early illustrations of the plum curculio.)

Beginning about 1830 there was a noticeable increase in the number of references and articles relating to this pest from practical fruit growers and others, giving their experience in the use of remedies and suggesting plans for circumventing its injuries. Some of the more important writers between 1830 and 1850 were David Thomas, S. Reynolds, R. P. Hildreth, William Wilson, B. Manley, Dr. Joel Burnett, John Parsons, A. J. Downing, James Matthews, C. E. Goodrich, and there were many others.

Excepting Melsheimer (see bibliography), the plum curculio appears to have been first treated by an American entomologist in 1819, when it was described as *Rhynchænus cerasi* and figured (fig. 3) by W. D. Peck, who considered it the cause of black-knot of cherries and plums, from the fact that the insect was reared from these

excrescences. In his Entomology of North America, published in 1831, Thomas Say refers to the curculio as *Cryptorhynchus argula*, and gives the opinion of his kinsman, Bartram, as to its destructiveness. A fairly extended account of the insect is given by Harris in his Insects Injurious to Vegetation, published in 1841, and it was considered at length by Dr. Asa Fitch in his address on the curculio and black-knot of plum trees, delivered before the New York State Agricultural Society in 1860 (p. 839).

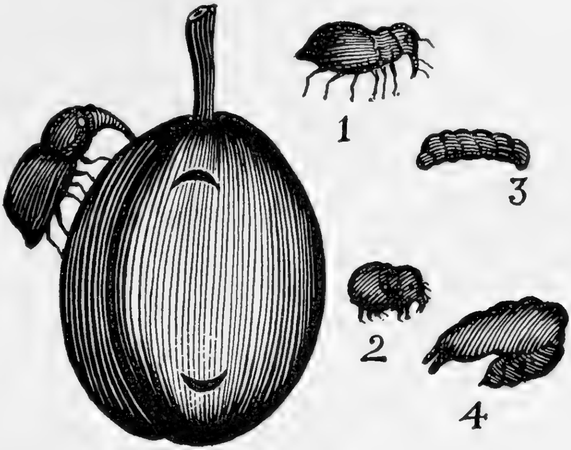


FIG. 2.—An early illustration of the plum curculio, frequently used between about 1830 and 1850.

The most complete account of the insect up to this time, however, was that by Dr. Isaac P. Trimble in his Treatise on the Insect Enemies of Fruits and Fruit Trees, published in 1865. In this work 99 quarto pages are devoted to the curculio, accompanied by 8 colored plates. Many observations are presented as a result of personal investigation. Important contributions to a knowledge of the insect are given in the articles by Walsh in the Practical Entomologist for 1867 (pp. 75–79), and in the First Annual Report on the Noxious Insects of Illinois (pp. 85–96). In the First Missouri Report, published in 1869, Dr. C. V. Riley gives an extended account of the curculio, summarizing the knowledge concerning it up to that time, and in the Third Missouri Report (1871, pp. 11–29) gives further information on its life history, with an ex-

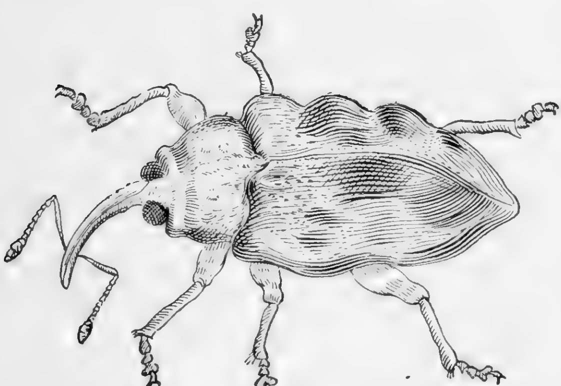


FIG. 3.—Peck's figure of the plum curculio, published with his description (*Rhynchænus cerasi*) in 1819.

tended discussion of apparatus for jarring. Also during the same year there was published in the American Entomologist (vol. 1, pp. 130–136) a popular account of the curculio, this being a lecture given by Dr. Riley before the Illinois State Horticultural Society. Numerous references, or more or less extended articles, concerning this insect are to be found in the writings of the earlier entomologists, as William Saunders, William Le Baron, Townend Glover, A. J. Cook, J. A. Lintner, and others, but the writings of Walsh and Riley were perhaps of most importance.

References to the plum curculio notably increased with the establishment of the agricultural experiment stations. Dr. S. A. Forbes, in Illinois, had already given some attention to this insect, publishing interesting observations on the use of poisons in its control as early as 1885. Experiments in spraying with arsenicals had been undertaken by W. B. Alwood, working under the direction of the entomologist of the United States Department of Agriculture, beginning with the season of 1887, and an extended summary account of the insect, by C. V. Riley and L. O. Howard, was published in the Report of the Commissioner of Agriculture for 1888. During this latter year Prof. C. M. Weed, of the Ohio Agricultural Experiment Station, began experiments in the use of arsenicals in its control, which were continued during the two or three subsequent seasons. Similar tests were reported by Prof. A. J. Cook in 1887 from Michigan, and in 1890 Prof. C. P. Gillette, in Bulletin 9 of the Iowa Agricultural Experiment Station, gave results of experiments and observations on the curculio and plum gouger carried out during the season of 1889.

A specific investigation of the curculio as an apple pest was begun by Prof. J. M. Stedman in Missouri in 1900 and continued during 1901 and 1902. Results of his investigations were given in Bulletin 64 of the Missouri Agricultural Experiment Station, published in July, 1904. Prof. C. S. Crandall, in Illinois, began in 1903 a thorough investigation of the insect as an apple pest, continuing the work during the following year. Results of his investigations and studies on the plum and apple curculios are published in Bulletin 98 of the Illinois Agricultural Experiment Station (1905) and comprise perhaps the most comprehensive account of the life histories of these two insects thus far given, as well as results of experiments with arsenical sprays on a commercial scale. The year following Prof. Forbes, in Bulletin 108 of the Illinois Agricultural Experiment Station (1906), reported results of experiments with arsenical sprays on a commercial scale, showing in connection with the work of Prof. Crandall that notably less injury to apples resulted following the thorough use of arsenate of lead. During the same year Prof. M. V. Slingerland reported results of cooperative spraying against the

curculio carried out during 1904 between the Agricultural Experiment Station of Cornell University (Bulletin 235) and certain fruit growers in western New York. Mr. E. P. Taylor, in Bulletin 21 of the Missouri State Fruit Experiment Station, reports results in spraying for the control of the curculio on apple as obtained by him in the Ozark regions of Missouri. Observations on the curculio and results of experiments are given by W. W. Chase in Bulletin 32 of the Georgia State Board of Entomology, published in 1910.

Beginning in 1905, investigations of the curculio were undertaken by the Bureau of Entomology of this department, and more or less attention has been given to this insect up to the present time. The investigation has included an inquiry into the life history and habits of the insect in various parts of the country and the carrying out of experiments in spraying on a commercial scale in its control on peaches, plums, and apples. As a result of the work in 1905, recommendations concerning the use of an arsenate-of-lead spray on peaches were given in the Yearbook of the Department of Agriculture for that year (p. 329) and in Circular 73 of the Bureau of Entomology. In the course of experiments to determine the comparative value of the one-spray method in the control of the codling moth much information was obtained on the value of spraying for the curculio, the results of which were published in Bulletin 80, Part VII, of the Bureau of Entomology.

A decided advance in spraying stone fruits, especially peaches, was made with the establishment of the practicability of the control of brown-rot, scab, and curculio on peaches by the use of a combined spray of lime-sulphur and arsenate of lead. Recommendations for the preparation and use of this spray were given in Circular 120 of the Bureau of Entomology, and in Farmers' Bulletin 440 results of further experiments and demonstrations were given.

In the foregoing historical sketch it has been attempted to indicate only the principal contributions or landmarks in the progress of knowledge concerning this insect and the remedies against it. By turning to the bibliography (p. 219) the reader will find reference to most of the contributors, although the list of titles could still be considerably lengthened.

DISTRIBUTION.

The curculio is indigenous to the eastern United States, and has probably always occupied about its present range of distribution. In some of the earlier accounts of the insect the inference is given that it had gradually spread westward from more eastern regions. As shown elsewhere (p. 156), its injuries were first noted in the neighborhood of Philadelphia about 1736.

Under the caption, "The curculio in Michigan," a Mr. Adrian, writing in The Cultivator in 1852, says:

I propose in this communication to speak of the progress of the curculio in southern Michigan. I have been a resident of Lenowee County for the last 18 years. The first depredations of this insect commenced about six years ago, the first season attacking only a few of our choicest plums; the succeeding year they were more numerous, and since continue to increase from year to year, puncturing every variety of plum and also cherries to a considerable extent and in some instances often, apples.

Dr. Asa Fitch in his Essay, published in 1860, says:

As an evidence of its steady progress and increase [in New York State] during the past 40 years, I may state that in my boyhood the wild plum trees in my own vicinity were often well filled with fruit. But, though thrifty trees are still growing on several of the same places, I have never since that time seen a ripened plum upon any of them.

A more recent statement relative to the invasion by the curculio of new territory (in Wisconsin) within its range of distribution is that by Prof. E. S. Goff in Insect Life (vol. 6, p. 37):

Until recently the peninsula lying between Green Bay and Lake Michigan has been free from invasion by the curculio (*Conotrachelus nenuphar*), and until the present summer (1893) it has never been found in any part of this peninsula lying north of Sturgeon Bay so far as can be learned from fruit growers in that region. In consequence of this, plum growing is becoming an industry of some importance in that district.

Prof. Goff further states as a result of personal examination that he found the curculio south of the bay, but that north of the bay no infested plums could be found, though a few wormy cherries were noted for the first time in the experience of the fruit growers. The invasion apparently proceeded from the southwest.

Dr. B. D. Walsh, writing from Illinois in 1867, observes:

Although the curculio now infests the cultivated species of plums (*Prunus domestica* Linn.) to fully as great extent as our common wild species (*Prunus americana*), yet it is only at a comparatively recent date that it attacks our cultivated plums, and since that epoch it has been occurring every year worse and worse and making onslaughts on other fruits, such as peach and cherry, and even the apple.

"The curculio," said the Hon. D. B. Baker in 1855, "were unknown and never made their incursions into this region [Illinois] until some years after the organization of our State government, A. D. 1818. There can be little doubt, however, that the curculios have existed from time immemorial in our State, breeding in wild plums."

Numerous opinions of a similar nature might be cited to indicate the belief that the curculio was not indigenous to certain regions, and that it put in appearance only after cultivated food plants had been grown for some years. It seems more probable to the writers, however, as stated by Walsh, that the insect has always been generally distributed over its range, subsisting on wild food plants. The introduction of cultivated fruits undoubtedly resulted,

within a longer or shorter time, in these being attacked by the insect, and as it became abundant its injuries were sufficient to attract the attention of observant growers.

From records in literature and those obtained by the Bureau of Entomology the curculio is found to occur very generally at the present time throughout the Mississippi Valley and the territory to the eastward. Records of the insect are at hand from hundreds of localities, covering practically all of this territory. Interest attaches, however, to the western and northern limits of the occurrence of the curculio, and especially to the consideration of factors which may have operated to prevent its further spread.

WESTERN LIMIT OF OCCURRENCE.

During the summer of 1910 it was possible to collect some data on the western limit of occurrence of the curculio. In early June Mr. John B. Gill, of the Bureau of Entomology, was instructed to proceed to Sherman, Tex., and from thence in a northwesterly direction (along the Fort Worth & Denver City Railway) to a point where the curculio could not be found. Next, to proceed in a northeasterly direction (along the Atchison, Topeka & Santa Fe Railway) into territory where the species was abundant. Mr. Gill proceeded in this zigzag manner to the west and east of the one hundredth meridian, as far north as North Dakota, making collections at many points of wild and cultivated fruit which might be infested. This fruit was sent to the insectary at Washington where rearings were made. Owing to injury by late frosts, the fruit crop in some sections was very light or absent, and on this account the collections were not so representative as was desirable.

At Sherman, Tex., the insect was found on peaches and cultivated plums, though no injury was observed on apples. Four curculios were reared from sendings of fruit from this locality. The insect was also found present at Denison, Tex., an adjacent town on the Red River, five beetles being secured from fruit sent in. At Arlington, Tex., curculio larvæ were found in peaches and plums, but the attack in no case was severe. Three curculios were secured from fruit from this locality.

At Wichita Falls, Tex., the curculio was found on Japan and wild goose plums and peaches, and evidence of its injury to wild plums was noted. From several collections of fruit sent in no curculios were obtained.

At Quanah, Tex., no curculio attack was found, although the wild plums were slightly infested with the plum gouger (*Anthonomus scutellaris*). Plums collected from wild trees along a creek were sent in to the insectary and several plum gougers obtained, but no adults of the plum curculio.

At Amarillo, Tex., also, no indication of the presence of the curculio was noted in the wild plums growing along the Canadian River, and including several small peach, plum, and apple orchards in the region. No curculios were reared from the fruit sent from Amarillo. At Canadian, Tex., an abundance of wild plums was found along the Canadian River, but no curculio attack was observed. No beetles were obtained from the fruit sent in from this locality, although 8 plum gougers were obtained.

Both wild and cultivated plums at Alva, Okla., showed injury from the curculio. Two beetles were obtained from fruit collected in that region and sent in to the insectary.

The curculio was very much in evidence in the environs of Wichita, Kans., the next point visited, occurring in cultivated plums, and injury to apple was also noted. A total of 51 beetles was reared from three sendings of fruit from this locality. At Hutchinson, Kans., the insect was also abundant, infesting both wild and cultivated plums, apricots, and apples. Thirty-two beetles were secured from fruit sent in. At Salina, Kans., the insect was also in evidence, injury being noted in several orchards of cultivated plums as well as in this fruit growing wild. A total of 68 beetles was reared from fruit from this section, indicating its considerable abundance.

At Colby, Kans., no signs of curculio injury were found, nor were any beetles reared from the small amount of fruit sent in to the insectary from this locality. At Norton, Kans., the point next investigated, conditions were very similar to those obtaining at Colby, fruit being very scarce. No signs of curculio injury were noted nor were beetles reared from fruit received from this place.

At Grand Island, Nebr., the curculio was very much in evidence on wild and cultivated plums, a total of 74 beetles being reared from the fruit there collected. The insect was also present in numbers in wild and cultivated plums at North Platte, Nebr., a total of 57 adults being obtained from several collections of fruit. At Northport, Nebr., the complete absence of both native and cultivated fruit prevented any observations whatever.

However, at Sterling, Colo., in about the same latitude, curculio egg punctures were observed in wild plums, although they were nowhere abundant. No punctures were noted on apples during a careful search of several orchards. The fruit, however, was not abundant. From collections of wild plums sent in to the insectary two adults were reared. This appears to be the first record for the curculio from that State.

At Rapid City, S. Dak., cultivated and wild plums were found infested by the curculio to a slight extent. A total of 18 adults was reared from material from this place. At Pierre, S. Dak., the work

of the curculio was not much in evidence, although both wild and cultivated plums showed some injury. Fourteen beetles were reared from fruit from Pierre. At Aberdeen, S. Dak., practically all fruit had been destroyed and no observations on the curculio could be made.

Conditions were very similar at Jamestown, N. Dak., the point next visited. No fruit whatever was in evidence and no observations were possible. Also at Bismarck, N. Dak., the fruit had been completely destroyed. At Fargo, N. Dak, and Moorehead, Minn., an adjacent town, there was but little in the way of fruit, although wild plum trees were in abundance in the Red River Valley. Four curculios, however, were reared from plums sent in.

In this connection should be mentioned the record of the curculio at Aweme, Manitoba, collected by Mr. N. Criddle, and published in the Annual Report of the Entomological Society of Ontario for 1904, page 76.

While the observations made during 1910 by Mr. Gill are far from as complete as desirable, yet it appears clear that the insect has not established itself to any extent west of about the one hundredth meridian. Sterling, Colo. (longitude 103°), is the most western point from which the species has been recorded. Observations are most complete for Texas, and according to the data at hand the insect is present as far west as Victoria on the south and Wichita Falls on the north. Although fruit was present at Quanah, Canadian, and Amarillo, Tex., no beetles could be found. The general conclusion would appear warranted that the insect is not able to extend its range much out of the humid area as defined in Merriam's Life-Zone Map.

In Table I the localities above mentioned, with a few additional ones, are shown, with approximate longitude and with indications of the source of the record.

TABLE I.—*Western distribution of the plum curculio.*

Localities.	Longitude (approximate).		Occurrence.	Remarks.
TEXAS.	°	′		
Victoria	97	00	Present	Reared from fruit in 1905.
Garrison	94	30	do	Do.
Morrill	95	30	do	Specimens received from correspondent.
Arlington	97	00	do	Reared from fruit in 1910.
Sherman	96	35	do	Do.
Denison	96	30	do	Do.
Wichita Falls	98	25	do	Do.
Quanah	99	45	Absent	
Canadian	100	20	do	
Amarillo	101	45	do	
OKLAHOMA.				
El Reno	98	00	Present	Specimens received from correspondent.
Alva	99	30	do	Reared from fruit in 1910.

TABLE I.—*Western distribution of the plum curculio*—Continued.

Localities.	Longitude (approximate).		Occurrence.	Remarks.
KANSAS.	°	′		
Wichita	97	20	Present	Reared from fruit in 1910.
Salina	97	35	...do	Do.
Hutchinson	98	00	...do	Do.
Norton	99	50	Absent (?)	
Colby	101	00	...do	
COLORADO.				
Sterling	103	15	Present	Reared from fruit in 1910.
NEBRASKA.				
Lincoln	96	45	Present	Specimens received from correspondent.
Grand Island	98	25	...do	Reared from fruit in 1910.
North Platte	100	50	...do	Do.
SOUTH DAKOTA.				
Aberdeen	98	30	(?)	Destruction of fruit crop by cold prevented observations.
Pierre	100	25	Present	Reared from fruit in 1910.
Rapid City	103	15	...do	Do.
NORTH DAKOTA.				
Fargo	96	50	Present	Reared from fruit in 1910.
Jamestown	98	45	(?)	Destruction of fruit crop by cold prevented observations.
Bismarck	100	50	(?)	Do.
MANITOBA.				
Aweme	99	00	Present	Collected by N. Criddle (Ent. Soc. Ont., 1904, p. 76).

NORTHERN LIMIT OF OCCURRENCE.

The data bearing on the distribution of the curculio to the north depend almost entirely upon records in the Reports of the Entomological Society of Ontario and in Dr. James Fletcher's reports as entomologist of the Canadian Experimental Farms. The most northerly point is Aweme, Manitoba, previously mentioned in considering the western occurrence of the insect. This is in north latitude about 49°. The insect is also recorded from Gore Bay, Manitoulin Island, Ontario, north latitude about 46°, and at Ottawa and Owen Sound, Ontario. According to Prof. William Lochhead, the insect was quite prevalent in Quebec Province during 1909. There are three records from Nova Scotia, namely, Berwick, Wolfville, and Port William, all in the immediate vicinity of one another in north latitude 45° 30′. So far as we have been able to determine, the localities mentioned above mark the northern occurrence of the curculio. The insect apparently is quite prevalent throughout Ontario and the lower St. Lawrence region of Quebec Province.

Table II gives these localities with the approximate north latitude and the bibliographical references.

TABLE II.—*Northern distribution of the plum curculio.*

Localities.	Latitude.	Remarks.
	° ′	
Aweme, Manitoba	49 00	Collected by N. Criddle (Rept. Ent. Soc. Ont., 1904, p. 76).
Gore Bay, Manitoulin Island, Ontario	46 00	Wm. Saunders (Rept. Ent. Soc. Ont., 1880, p. 8).
Ottawa, Ontario	45 30	W. Hague Harrington (Rept. Ent. Soc. Ont., 1880, p. 53).
Owen Sound, Ontario	44 35	Fletcher (Rept. Ent. Exp. Farms Canada, 1885).
Quebec, Quebec	46 35	Wm. Lochhead (Rept. Ent. Soc. Ont., 1909, p. 68).
Berwick, Nova Scotia	45 30	Fletcher (Rept. Ent. Exp. Farms, Canada, 1896, p. 255).

SOUTHERN LIMIT OF OCCURRENCE.

The most southerly location in the United States from which we have records of this species is Victoria, Tex., in the southwest, and around Hampton, Fla., in the southeast. At the latter place the insect has been found very abundantly and it constitutes a very serious pest to peach growers. At Deland, Fla., to which is adjacent a considerable peach-growing industry, no trace of the insect could be discovered, although it should undoubtedly thrive in that locality. These observations, however, were made in 1905 and the insect in the meantime may have become established there.

DISTRIBUTION OF THE CURCULIO ACCORDING TO LIFE ZONES.

From the foregoing discussion it will be noted that the plum curculio is present in the humid area in all of the life zones except the Tropical. It is most abundant and destructive, however, in the

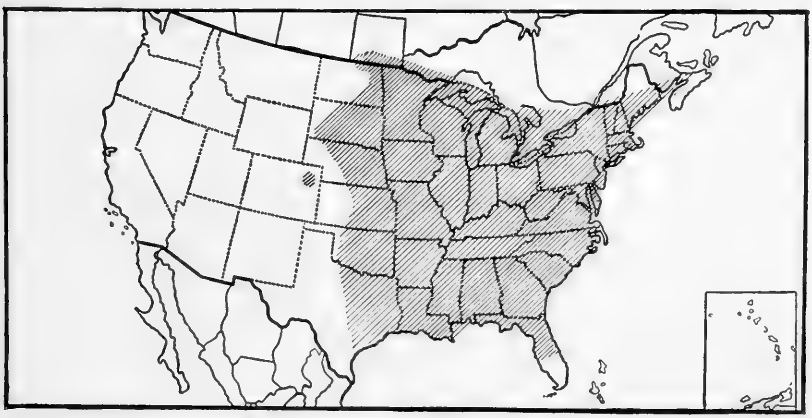


FIG. 4.—Map showing by the shaded area the distribution of the plum curculio. (Original.)

Upper and Lower Austral Zones. While generally present throughout the Transition Zone it would appear to be much less of a pest than to the southward. Sufficient data are not at hand to indicate its relative importance in the Canadian Zone, though it is probably occasionally quite destructive, as indicated by the observations of Dr. Fletcher, Prof. Lochhead, and others. In figure 4 the shaded area indicates the present distribution of the curculio in so far as we have been able to determine it.

REPORTED INTRODUCTIONS OF THE CURCULIO.

There have been reports at different times of the introduction of the plum curculio into new localities in the United States and into foreign countries. Thus in 1889 it was reported by local newspapers as present in Los Angeles County, Cal., but the insect in question proved to be Fuller's rose-beetle (*Pantomorus fulleri*) (see fig. 8), a common insect in the West, feeding upon leaves of evergreens, oaks, camellias, palms, cannas, etc.

In Bulletin 51 of the Montana Agricultural Experiment Station the insect is stated to be present in the Bitter Root Valley, but this reported introduction was later found to be without foundation.

The curculio was reported in British Columbia on plums, but upon investigation in the territory reported to be infested, none of the insects could be found.

The curculio is the subject of a chapter in the Handbook of the Destructive Insects of Victoria, Part II, by Mr. Chas. French, in which he alludes to the discovery by a Mr. Parson, of Kent, of an insect injuring plums very similar to if not identical with the plum curculio. The correctness of this record, however, is plainly doubted by Mr. French, and his reason for a detailed consideration of the insect in the work mentioned results from his expressed fear that the species may before long find its way into Australia. Thus far, however, the insect appears not to have been introduced there.

In Tasmania, during 1889, considerable excitement was aroused by the discovery in cherries around Hobart of grubs which were thought to belong to our North American plum curculio. Subsequent records as to the correctness of this belief are wanting, but it is probable that the insect in question was some one of the native species.

More recently, in 1900, the insect was reported in New Zealand, near Auckland, but careful search for it in the supposedly infested territory did not reveal any trace of its presence. So far as recorded, therefore, the plum curculio is limited to the territory previously indicated in North America. It appears remarkable that in the case of an insect infesting fruits in the larval stage it should not have become much more widely distributed in the United States and to foreign countries. In fact it is entirely reasonable to suppose that at one time or another the insect has been shipped along with fruit to various parts of the world, but that owing to certain conditions essential for its proper development it has not been able to establish itself. In any country with climatic conditions similar to those obtaining in the humid area of the United States it would doubtless thrive, however, and become as destructive as it is at the present time in North America.

LOSSES DUE TO THE PLUM CURCULIO.

It is difficult to make even an approximate estimate of the shrinkage in value resulting from the attack of the plum curculio on its several food plants. While adequate statistics are not available on which to make accurate calculations of the value of these several crops in the territory occupied by the insect, an attempt has been made to indicate as closely as possible the approximate annual money loss from the curculio. These data were published, as a part of an article on the losses from deciduous-fruit insects, in the Report of the National Conservation Commission, Volume III, page 309. In this article the figures for the apple crop were obtained from the American Agriculturist and other figures from the Twelfth Census. That portion relating to the curculio is quoted below.

Average apple crop in the infested territory, 1897 to 1907.

Barrels	34, 292, 700
Estimated shrinkage of first-class fruit, 10 per cent	3, 429, 270
Value, at $1.25 per barrel	$4, 286, 587
Value of fruit as culls, at 30 cents per barrel	1, 028, 781
Total losses to apples	3, 257, 806

On apples this insect receives but little if any treatment aside from that given in codling-moth treatment.

There are no available figures on the yield of peaches. It was thus necessary to determine this as accurately as possible on the basis of the number of trees, and a conservative yield which each should give.

Trees in infested territory	90, 931, 542
Assuming that one-fourth bear every year, producing an average of 1 crate per tree, valued at 50 cents, net value	$11, 366, 443
Estimated annual loss of 33 per cent	3, 788, 814
Cost of spraying, jarring, etc	300, 000
Total	4, 088, 814

There are likewise no figures on the yield of the plum, prune, etc., and the yields of these fruits were determined in a similar manner.

Trees in infested territory	15, 906, 398
Assuming that one-fourth bear fruit every year at the rate of 1 crate per tree, at 50 cents value	$1, 988, 299
Estimated annual loss of 50 per cent	994, 149
Cost of treatment, spraying, jarring, etc	250, 000
Total	1, 244, 149

TOTALS.

Apple	$3, 257, 806
Peach	3, 788, 814
Plum, prune, etc	994, 149
Total	8, 040, 769
Cost of treatments	550, 000
Grand total	8, 590, 769

The foregoing shows a grand total of loss each year, including cost of remedial operations resulting from the attack of the curculio, of about $8,500,000. This amount, while by no means large as measured by the destruction caused by certain other insect pests, as the cotton-boll weevil, Hessian fly, etc., is nevertheless a heavy drain upon the fruit-growing industry of the country. Unquestionably this injury will be reduced more and more in the future following a more general adoption of spraying, especially of peaches and plums—now entirely feasible, as elsewhere shown (p. 214).

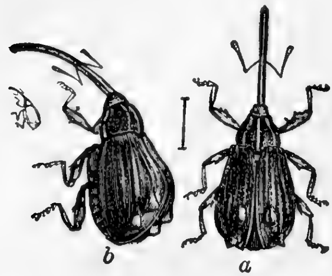


FIG. 5.—The apple curculio (*Anthonomus quadrigibbus*). (From Riley.)

The sum total of losses due to the ravages of the curculio during the past 175 years would amount to an exceedingly large sum, though its injuries have become especially noticeable within comparatively recent years along with the enormous development of the fruit-growing industry. During the past 25 or 30 years the total losses caused by this insect, to the various fruits which it attacks, would on a conservative estimate probably be not less than $100,000,000.

INSECTS LIKELY TO BE MISTAKEN FOR THE PLUM CURCULIO.

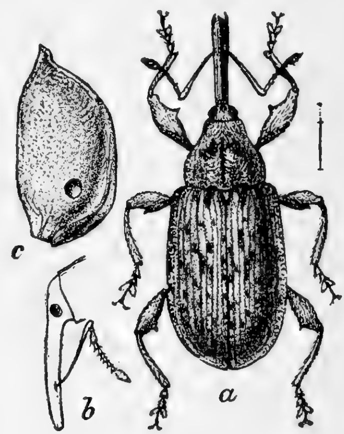


FIG. 6.—The plum gouger (*Anthonomus scutellaris*). (From Insect Life.)

The work of the plum curculio is well known to most fruit growers within its area of distribution, and many have seen the adult or beetle. Others, however, know the insect only from its work, or as the grub or worm in the peach, plum, or cherry. Not infrequently specimens of beetles are received by the Bureau of Entomology from correspondents who believe them to be the plum curculio, and which, while mostly true snout beetles, are quite different from this insect. Among those thus likely to be mistaken for the curculio are the following:

The apple curculio, *Anthonomus quadrigibbus* Say (fig. 5).

The plum gouger, *Anthonomus scutellaris* Lec. (fig. 6).

The acorn weevil, *Balaninus victoriensis* Chitt. (fig. 7).

Fuller's rose-beetle, (*Aramigus*) *Pantomorus fulleri* Lec. and Horn (fig. 8).

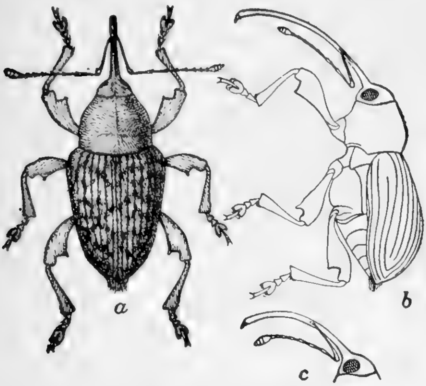


FIG. 7.—The acorn weevil (*Balaninus victoriensis*). (From Chittenden.)

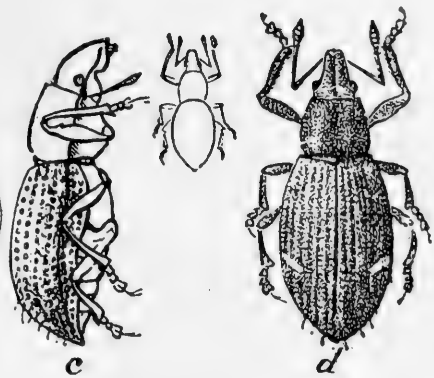


FIG. 8.—Fuller's rose beetle (*Pantomorus fulleri*). (From Chittenden.)

The imbricated snout-beetle, *Epicærus imbricatus* Say (fig. 9).

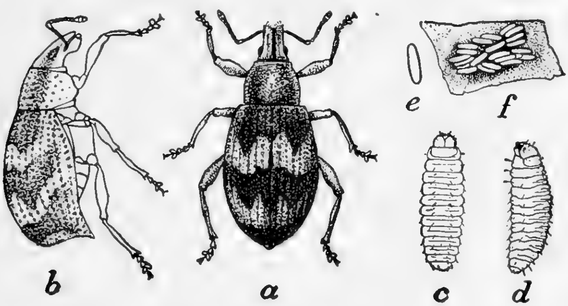


FIG. 9.—Imbricated snout beetle (*Epicærus imbricatus*). (From Chittenden.)

Comparison of the illustrations of these several species with figures of the plum curculio will show important differences.

DESCRIPTION.

THE EGG.

The egg of the plum curculio (see fig. 10) is rather broadly elliptical, dilute milky-white in color, the surface smooth and shiny; the micropyle is inconspicuous, and the ends indistinguishable. The length is variable; measurements of many specimens show a variation of from 0.43 to 0.72 mm., with a range in width of from 0.35 to 0.45 mm. The average size of 30 eggs was found to be 0.643 by 0.411 mm.

FIG. 10.—The plum curculio (*Conotrachelus nenuphar*): Egg. (Original.)

THE LARVA.

When full grown—length 6 to 9 mm., breadth 1.75 to 2.5 mm.; a yellowish-white, footless grub; nearly cylindrical, slightly flattened on ventral side; body curved toward ventral side, bow-shaped; sides of each segment from second thoracic to eighth abdominal expanded into a fleshy lobe above and below a depressed lateral line. (See figs. 11 and 12 and Pl. I, fig. 3.)

Head as broad as long, about 1 mm. each way; color nut-brown; epistoma, clypeus, labrum, and mandibles darker; epicranial suture and its continuation as a median line

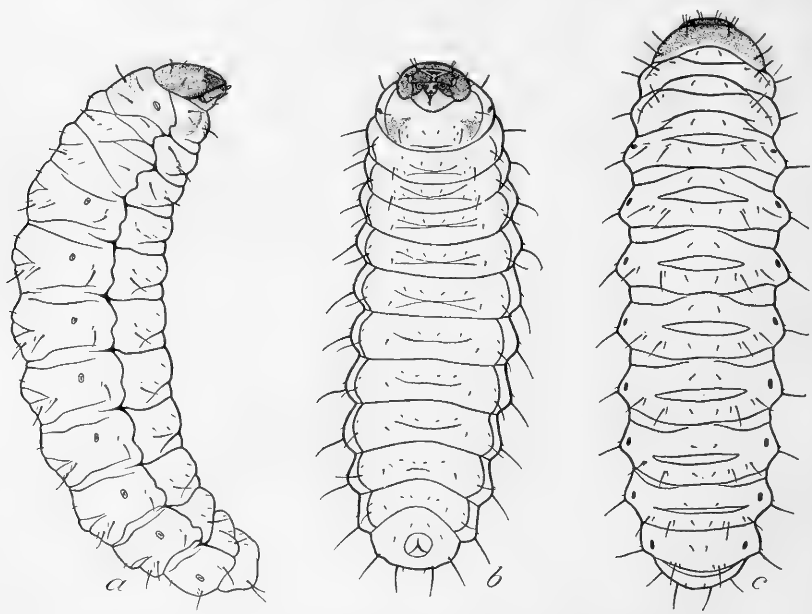


FIG. 11.—The plum curculio: Larva, showing structural details.—*a*, lateral aspect; *b*, ventral aspect; *c*, dorsal aspect. (Original.)

extending beyond the middle of the front also darker; frontal suture light yellow, submentum yellowish white; antennæ minute, one-jointed, situated at base of mandibles at ends of frontal suture; minute eye-spots usually present directly laterad and caudad of antennæ; mandibles with two blunt teeth; palpi two-jointed; seven hairs on each side of the epicranium, two on the front, two on epistoma, two large and many small hairs on labrum, two on each mandible, two on submentum, two on mentum, one

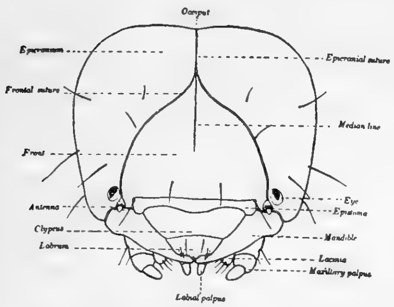


FIG. 12.—The plum curculio: Head of larva, with parts named. Much enlarged. (Original.)

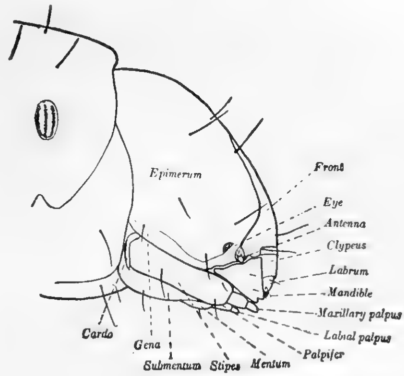


FIG. 13.—The plum curculio: Head of larva, lateral aspect, with parts named. (Original.)

on stipes, two on palpifer, and eight on lacinia; hairs arranged as shown in figures 13 to 15.

Thorax.—Prothorax with a light brown chitinized shield on the dorsum and a slightly chitinized area on each side of the venter; a conspicuous oblong spiracle situated above the middle of the side, its long axis extending dorso-ventrally; three pairs of large hairs on the dorsum, two pairs of large and five pairs of minute hairs below the lateral line, arranged as shown in figures.

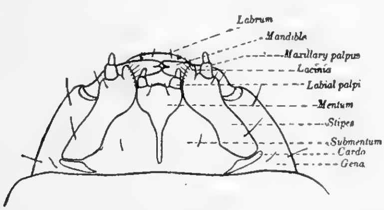


FIG. 14.—The plum curculio: Head of larva, ventral aspect, with parts named. Much enlarged. (Original.)

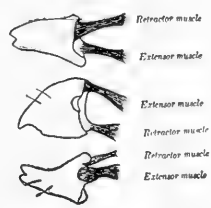


FIG. 15.—The plum curculio: Lateral, dorsal, and ventral aspects of right mandible of larva, with muscles. Much enlarged. (Original.)

Mesothorax and metathorax without spiracles; each with one pair of large and four pairs of minute hairs on the dorsum, a large hair on the upper and one on the lower lateral lobe, one pair of large and four pairs of minute hairs on the venter, arranged as shown in figure 11.

Abdomen.—Segments 1 to 7 each with an oblong spiracle above the middle of the side, its long axis extending longitudinally; two pairs of large and three pairs of minute hairs on the dorsum, one large and one minute hair on each lateral lobe, and three pairs of minute hairs on the venter, arranged as in the figures.

The eighth abdominal segment is smaller than the preceding and lacks the outer pair of large dorsal hairs.

The ninth abdominal segment is considerably smaller than the preceding, truncate posteriorly, has no spiracles, and bears two pairs of large and one pair of minute hairs on the posterior dorsal margin and two pairs of minute hairs on the venter.

The anus, surrounded by three anal lobes, is situated on the ventral posterior part of the ninth abdominal segment.

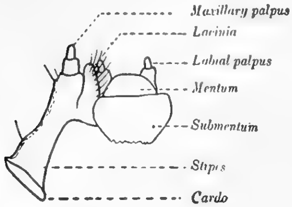


FIG. 16.—The plum curculio: Dorsal aspect of maxilla and labium of larva, with parts named. Much enlarged. (Original.)

THE PUPA.

Length 4.5 to 7 mm.; breadth 2.3 to 3.75 mm.; color white, in older specimens the eyes becoming reddish brown and then black and the mandibles and the tarsal claws becoming chitinized and visible through the pupal skin. A round spiracle is visible on the side of the second to fifth abdominal segments, that on the first segment being covered by the pad of the elytron.

The hairs of the pupa, except those on the head, legs, and some on the prothorax, arise from tubercles and are easily broken off. On the head there is a pair of large hairs near the vertex, a pair just above the eyes, a pair between the eyes, a pair on the front of the beak just above the insertion of the antennæ, a pair of smaller hairs lower down the beak, and a more widely separated pair of minute hairs still lower down the beak. There are eight pairs of hairs on the prothorax, two pairs on the mesoscutum, two on the metascutum, and two pairs on the distal end of each femur. The pads of the elytra are elevated into ridges, from which arise groups of hairs on tubercles, there being about seventeen hairs on each elytron. Abdominal segments 1 to 6 each bear two pairs of dorsal and one pair of lateral hairs. The seventh segment has an additional pair of lateral hairs, while the eighth segment has only one pair of

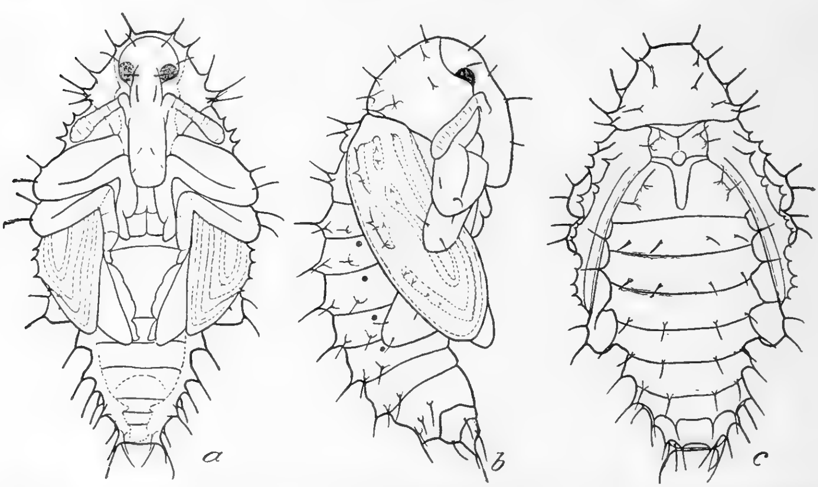


FIG. 17.—The plum curculio: Pupa, showing structural details—*a*, ventral; *b*, lateral; and *c*, dorsal aspects. (Original.)

dorsal and one pair of lateral hairs. The ninth segment has a stout spine and a hair rising from a tubercle on each apical angle, and a pair of hairs on the venter. (See fig. 17 and Pl. I, fig. 4.)

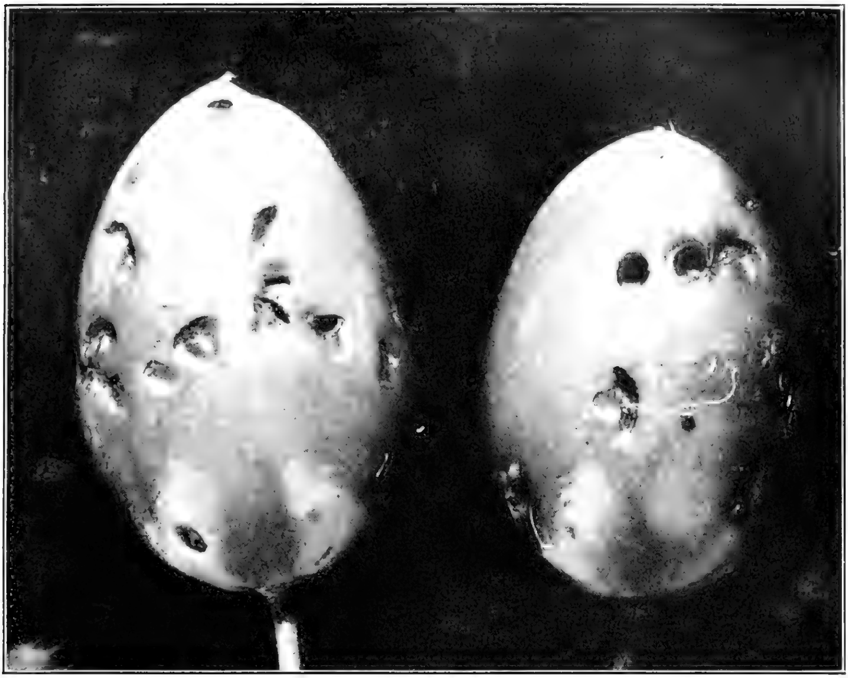


FIG. 1.—EGG AND FEEDING PUNCTURES ON YOUNG WILD-GOOSE PLUM. ENLARGED. (ORIGINAL.)

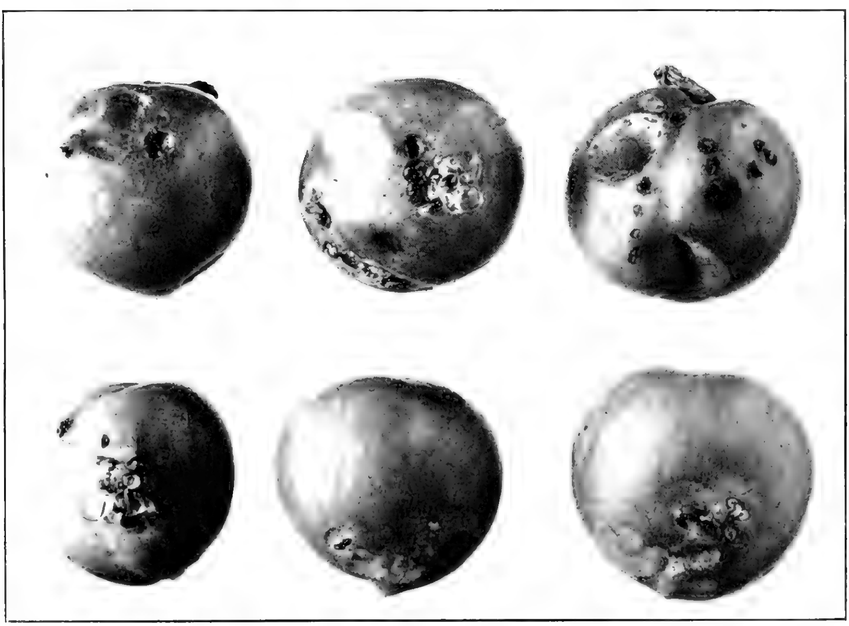


FIG. 2.—NEARLY RIPE WILD PLUMS, SHOWING EGG SCARS AND GUM EXUDATION FROM FEEDING PUNCTURES. (ORIGINAL.)

WORK OF PLUM CURCULIO ON PLUM.

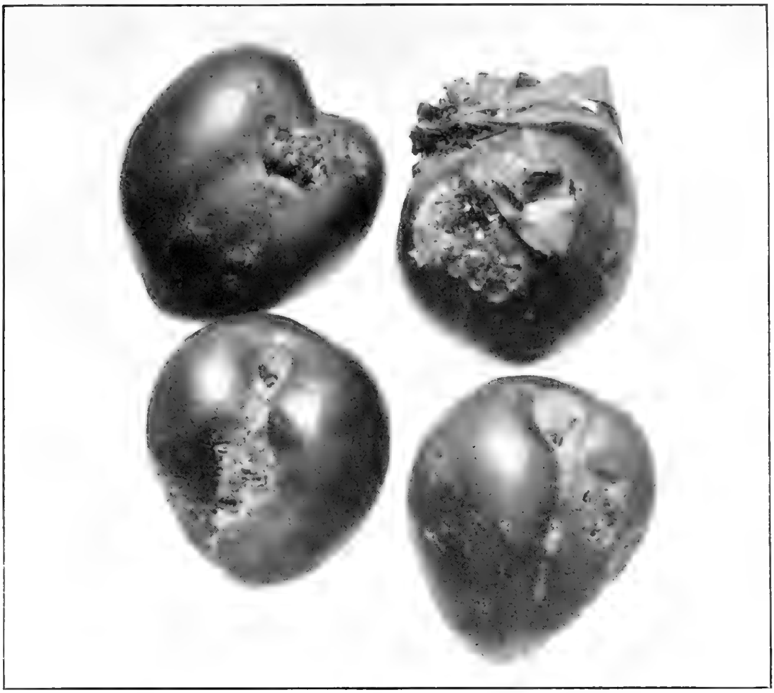


FIG. 1.—EFFECT OF EGG AND FEEDING PUNCTURES, WITH GUM EXUDATIONS, ON RIPE JAPANESE PLUMS. (ORIGINAL.)

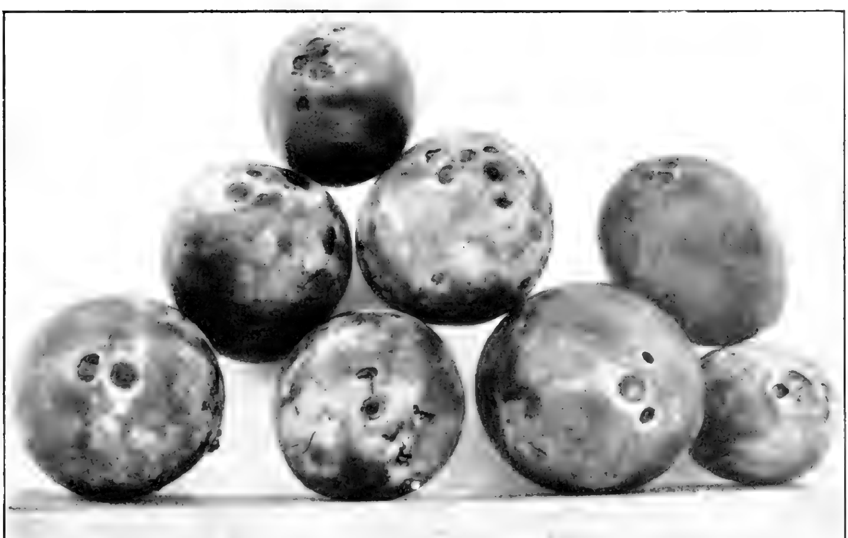


FIG. 2.—FALL FEEDING PUNCTURES ON RIPE PRUNES. (ORIGINAL.)

WORK OF PLUM CURCULIO ON PLUM.

THE ADULT.

Length 3.5 to 5.75 mm.; breadth 1.75 to 2.75 mm. This stage is too well known to require particular description. The original description by Herbst is given on pages 13 and 14. (See Pl. I, figs. 1 and 2; Pl. IV, fig. 1; text fig. 18.)

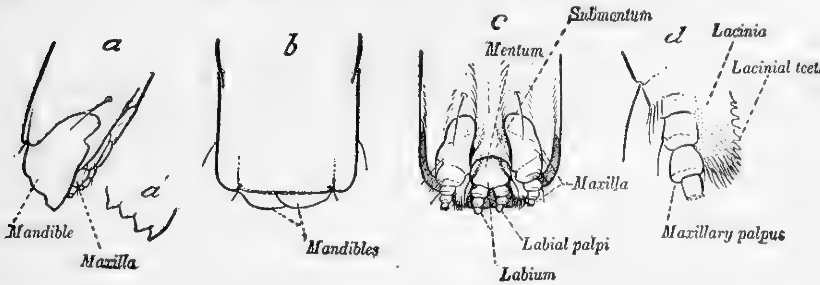


FIG. 18.—The plum curculio: Mouth parts of the adult—*a*, and *a′*, mandibles, lateral aspect; *b*, dorsal aspect; *c*, ventral aspect; *d*, maxillary palpus. Much enlarged. (Original.)

FOOD PLANTS.

The plum curculio feeds upon and oviposits in practically all pome and stone fruits, as the apple, pear, quince, plum, peach, cherry, nectarine, and apricot. Certain wild fruits are also more or less used, especially when those above mentioned are scarce, as Cratægus, crab apple, etc. There are records of oviposition in huckleberry, grape, strawberry, gooseberry, currant, and wild persimmon (*Diospyros virginiana*). There are also numerous records in literature of the breeding of this insect in black knot (*Plowrightia morbosa*), which we were able to verify during 1910. Not all fruits used by the female for egg-laying purposes, however, furnish suitable food for the growth and maturation of the larva, and from this standpoint the instinct of the parent beetle is often faulty. Nevertheless, there is evident choice of fruits for oviposition and, as stated by Trimble many years ago, in about the following order: Nectarine, plum, apricot, apple, pear, and quince. This order of preference nearly agrees with that indicated by our own observations, but Trimble does not include the cherry and peach, which we would place after plum, with the position of nectarine doubtful, as we have made but few observations on this fruit.

It must not be understood, however, that in the presence of all of these fruits the curculio will choose certain kinds to the neglect of others. As a matter of fact, in orchards of mixed fruits, as plum, peach, apple, and pear, all of these sorts will be freely punctured; but plums more so, as a rule, than the others. The insect undoubtedly prefers smooth-skinned fruits, and in the case of plum, nectarine, and apricot, which are usually first to attain sufficient size to receive the eggs, these are always much used. Nectarines and

apricots are very uncertain croppers throughout the range of distribution of the insect on account of early blooming and consequent injury by frost. During fruiting years, however, in the absence of treatment, practically none of the fruit of these varieties escapes puncturing. During June, 1910, one of the writers examined several hundred apricots from trees in a neglected home orchard near Bluemont, Va., without finding a single specimen free from infestation.

As a group, plums constitute the favorite food of the curculio, and the various species of wild plums were without doubt the original native food of this species, and are freely used at the present day. The early literature of the curculio abounds with references to its especial injury to cultivated plums, and growers of this fruit have complained bitterly of its ravages. With the extension of culture of other fruits, as peaches, apples, cherries, etc., its injuries to these fruits have likewise become more and more important. However, until in comparatively recent years the curculio was regarded as preeminently an enemy of plums. (See Pls. II and III, showing curculio injury to plums.)

Cultivated varieties of plums appear to show variation as to susceptibility to attack. There are frequent references in literature to the subject, but adequate data for conclusions are wanting. In an extended article Mr. D. B. Wier (Bulletin 14, old series, Division of Entomology, p. 39, 1887) presents under the caption "The native plums: How to fruit them—they are practically curculio proof," results of observations which led him to believe that native plums are especially sought for by the curculio for oviposition purposes. Thus—

> The first and most important is that of evidence showing that this insect seeks native plums in preference to all other fruits in which to deposit her eggs. This is a queer fact in biology which naturalists will be inclined to dispute, namely, that an insect should seek and use seemingly by preference a fruit in which to lay her eggs wherein but very few of them will hatch and in which but one of such larvæ as do hatch can be nourished on its substance to maturity.

Further on he states:

> I found that for every egg that hatched, and the larvæ had fed noticeably, that there were from 1,500 to 1,900 ovipositing marks of the curculio and that only one living curculio maggot was found in 3,100 to 2,500 plums examined, and in which her eggs had been laid. These percentages are from the June observations of these two years and coincide with previous observations.

Mr. Wier also observes:

> The reason why the plum curculio does seek the native plums to oviposit in seems to be because of their very early and fragrant bloom.

His observations that native plums are much sought for as places for egg laying and that the larvæ are not able to develop therein, led

him to recommend the planting of native plums among other sorts more subject to attack for the protection of the latter. In this way he believed that the curculio could be largely exterminated. To the conclusions and premises expressed by Mr. Wier, Riley and Howard have indicated their dissent in a footnote to the article in question and also in their article on the curculio in the Report of the Entomologist for 1887.

Riley states in the First Missouri Report, page 53—

That they prefer smooth-skinned to rough-skinned fruit.

That up to the present time the Miner and other varieties of the Chickasaw plum have been almost entirely exempt from their attacks and that in the Columbia plum the young larvæ are usually drowned out before maturing.

Under the caption "Plums for the million," Riley, in the American Entomologist, volume 1, page 92, further calls attention to the Miner and Columbia plums on account of their freedom from curculio injury.

Observations by Prof. Gillette in Iowa in 1889 include results of studies of varieties of plums as to their attractiveness to the curculio. The following plums were examined and the percentages of injury by the curculio were found to be as stated:

	Per cent.
Miner	2.50
Wolf	17.30
Chickasaw	15.70
Forest Rose	13.60
Native Seedling No. 1	8.30
Native Seedling No. 2	25.80
Native Seedling No. 3	5.20
Yellow Mira Bell	66.00
Black Prune	14.00
Bier	31.50
Early Red	19.00

The four varieties last mentioned are of the Domestica, or European type, the others being native. Mr. Gillette, in discussing the data, says:

That of the European varieties an average of 46.8 per cent of all plums were injured, the maximum being in the case of the Yellow Mira Bell, the minimum of injury being to the Black Prune, namely, 14 per cent. The average injury to native plums and varieties was only 6.6 per cent, with maximum in the case of a native seedling. The several small trees of *Prunus simonii* carried their fruit to maturity without any signs of curculio injury.

Mr. Gillette concludes that this insect has a decided preference for the *domestica* varieties.

From our own observations we would place Japanese varieties (*Prunus triflora*) and their hybrids and crosses at the head of the plum list, as most susceptible to curculio injury, and the varieties of

Prunus americana last, as least susceptible. Between these would come such native species and their varieties as *Prunus angustifolia* (Chickasaw) and *P. umbellata*, the *P. hortulana* group, and varieties of the European plums (*P. domestica*). Practically all sorts of plums throughout the range of the insect are freely attacked, but the earlier and more tender-skinned kinds will evidently be most sought out for egg-laying and feeding purposes.

With peaches, there appears to be little if any difference as to the amount of injury to the different varieties. (See Pls. IV to VI for illustrations of injury to peaches.) While the fuzzy skin of this fruit renders it less attractive to the insect than plums, peaches are, as a rule, generally used where the insects are at all abundant. In the South, where early and midseason varieties are almost exclusively grown, wormy fruit is always in evidence at picking time. In the Middle States, but especially in the Northern States, wormy ripe peaches are less frequently seen, although the injury to the young fruit may have been severe. Late-maturing varieties, as Salway, Smock, Bilyeu, etc., as stated by numerous observers, are more free from attack than midsummer and early varieties, growing under identical conditions. As these varieties ripen after most of the beetles have ceased egg laying, wormy peaches at picking time are correspondingly scarce. It is probably true, however, that during the active oviposition period of the beetles there will be no discrimination in choice of fruit of the early, midseason, and later maturing varieties.

In the case of the apple, the curculio appears to oviposit indifferently in all varieties early in the season, but later, on account of the changing texture of the skin and flesh, uses preferably the more tender varieties and those which mature during the summer or early fall. Such varieties as grow and mature quickly are very generally badly deformed from the egg and feeding punctures where the insect is abundant, whereas on later-maturing varieties the injury will be more nearly outgrown. (See Pls. VII to IX for illustrations of curculio injury to apple.) Late-fall and winter sorts are, however, often badly injured. Trimble says: "The early apples, as the Sweet Bough and Early Harvest, will suffer more than later kinds," evidently referring to the knotty condition of the fruit when ripe.

In regard to pears, all varieties appear to be about equally subject to attack. Larvæ, however, are probably never able to develop in the fruit on the trees, and comparatively few do so in drop fruit, especially such varieties as the Kieffer and LeConte. The injury to pears consists largely in deformity of fruit from the egg and feeding punctures. (See Pl. X.)

Sweet cherries are perhaps preferred to sour cherries, although varieties of both classes are freely punctured. Larvæ are able to

FIG. 1.—THE ADULT CURCULIO ON NEWLY SET PEACH. ENLARGED. (ORIGINAL.)

FIG. 2.—CURCULIO LARVA, OR GRUB, AND ITS WORK IN RIPE PEACH (ORIGINAL.)

WORK OF PLUM CURCULIO ON PEACH.

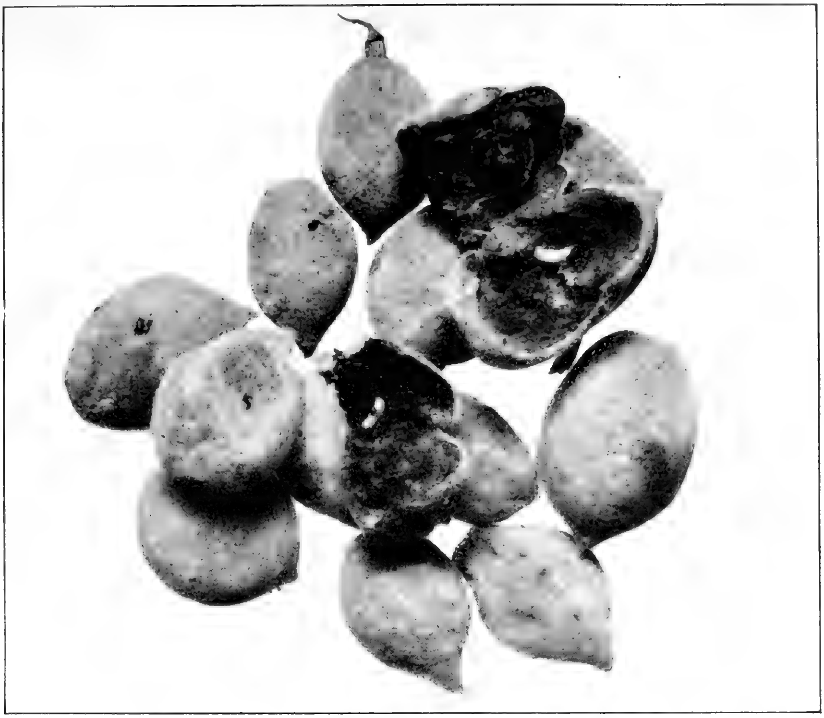


FIG. 1.—WORMY WINDFALL PEACHES. (ORIGINAL.)

FIG. 2.—PEACHES DEFORMED BY EGG AND FEEDING PUNCTURES. (ORIGINAL.)

WORK OF PLUM CURCULIO ON PEACH.

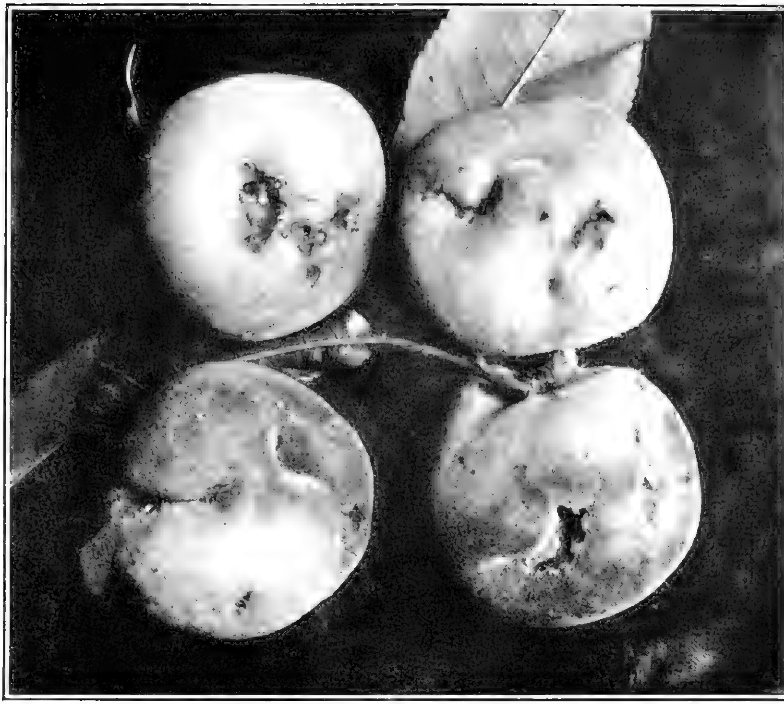


FIG. 1.—DEFORMED RIPE PEACHES. (ORIGINAL.)

FIG. 2.—GUM EXUDATION FROM CURCULIO PUNCTURES. (ORIGINAL.)

WORK OF PLUM CURCULIO ON PEACH.

develop in the fruit on the trees, and wormy ripe cherries are very generally present on the trees, and on the market. (See Pl. XI.)

There remains to be mentioned more particularly the recorded use, for egg-laying purposes and as food for larvæ, of the so-called black-knot of cherries and plums. (See fig. 19.) Prof. W. D. Peck, in the Massachusetts Agricultural Repository (vol. 5, p. 312, 1819), records rearing of the beetles from grubs found in the warty excrescences of a cherry tree, for which reason he gave it the name of *Rhynchænus cerasi*, or the cherry weevil. Grubs apparently the same as those found in the plums are stated to have been frequently observed in

FIG. 19.—Black-knot of plum, showing, on the left, infestation by plum-curculio larvæ. (Original.)

the warts, which it was then thought were caused by this insect. The larvæ observed by Prof. Peck went into the ground July 6 and on the 30th of the month the beetles began to appear. A résumé of Prof. Peck's observations on the curculio are given by Harris, who recommends that the excrescences of plum and cherry trees be cut out each year after the last of June. He adds that the moose plum (*Prunus americana*) seems to escape the attack of the insect, for no warts are found upon it even when growing in the immediate vicinity of diseased foreign trees. In his Essay Dr. Fitch, in commenting

on the nature of black-knot, states that the larvæ of the curculio are almost always found in these growths, and the grubs consume nearly all the spongy matter of the warts. Later he adds:

> We think the fact well established that this insect breeds in these black-knot excrescences with about the same avidity that it does in young fruit, notwithstanding these substances are unlike each other.

Dr. Fitch expresses the belief that the curculio also resorts to the bark of different fruit trees in which to deposit its eggs when it can find no young fruits to meet its wants, and cites Melsheimer's (A Catalogue of the Insects of Pennsylvania, 1806, p. 28, No. 589) statement 50 years earlier that the curculio bred in the bark of peach trees as well as in the fruit. Dr. Fitch also records finding numerous curved incisions in the bark of pear resembling those made by the curculio, causing little blister-like elevations, containing from 4 to 6 minute footless maggots which he thought belonged to the curculio, the insect wintering in the larval condition in the bark. In the First Missouri Report Riley states that the curculio deposits and the larvæ mature in the black-knot of plum, and quotes Dr. Hull to the effect that it oviposits in vigorous shoots of peach, but that the larva does not mature in these shoots.

Dr. Trimble says that black-knot, so often found on plum and cherry trees, is used freely by the curculio. These knots are often several days in advance of the young fruit, and the female curculio has been known to exhaust her supply of eggs in them before the young cherries or plums on the same trees were full formed. These positive statements as to the breeding of the insect in black-knot are scarcely to be questioned.

During the season of 1910 we were able to verify these records. From a quantity of fresh black-knot material cut from a European variety of plum in full fruit at Bluemont, Va., one beetle was reared. Mr. A. G. Hammar, however, at Douglas, Mich., found the curculio breeding very abundantly in black-knot on plums and cherries and succeeded in rearing many hundreds of adults. (See fig. 19.) The comparative scarcity of suitable fruit in the neighborhood was doubtless responsible for the great extent to which black-knot was used by the insect.

Fruits in which the larvæ fail to mature.—As already indicated, oviposition may occur in numerous fruits which are hardly fitted for the future development of the larvæ. As will be shown under another caption (p. 56), there is a considerable mortality of eggs and larvæ in all classes of fruit which do not fall to the ground; but in the case of pears, and doubtless the grape, huckleberry, persimmon, and similar fruits recorded as used for egg laying, the larvæ would in most cases be unable to mature. This has been shown to be true in the case of

the pear, the young fruit of which upon falling dries, becoming more or less flinty. Many hundreds of Kieffer, LeConte, Duchess and other varieties of pears have been collected, but in only a few cases were adults reared therefrom.

LIFE HISTORY AND HABITS.

THE EGG.

NUMBER OF EGGS DEPOSITED.

The number of eggs deposited by the curculio was long a matter of conjecture. Riley's estimate (First Missouri Report, p. 54) of from 50 to 100 has been generally quoted in the absence of definite observations. He further states that eggs are deposited at the rate of from 5 to 10 a day, the activity of beetles varying with the temperature. Prof. A. J. Cook, by dissection, found that a single female may contain 30 eggs. Dissections during early May, 1887, by Mr. W. B. Alwood showed the presence of only 1 or 2 fully developed eggs, although many immature ova were found. Late in May, however, 4 to 10 eggs were found in each female. Riley and Howard[1] in 1888 expressed belief in Riley's earlier estimate, as based on the rate of development, dissections, and observations.

The first attempt to obtain more exact information on this point was apparently in 1902, during the spring of which year Messrs. Quaintance and Smith[2] made observations in Maryland on 9 females confined separately during their lives and supplied daily with fresh plums. Careful examinations of the fruit were made and the number of eggs deposited by each female daily recorded.

The record is shown in abstract in the table below, from date of capture, May 14, to time of death of each individual.

TABLE III.—*Egg-laying records from 10 plum curculios, College Park, Md., 1902.*

No. of individual.	Eggs laid each week by each individual.												Total.
	May 14-20.	May 21-27.	May 28-June 3.	June 4-10.	June 11-17.	June 18-24.	June 25-July 1.	July 2-8.	July 9-15.	July 16-22.	July 23-29.	July 30-Aug. 5.	
1	37	75	43	20	24	14	14	6	3	10	21	9	276
2	65	91	40	26	11	2	......	......	......	......	......	......	235
3	......	......	......	......	......	......	......	......	......	......	......	......	......
4	62	102	59	51	28	2	......	......	......	......	......	......	304
5	70	104	64	45	36	25	14	9	6	20	30	13	436
6	64	67	56	51	27	5	......	......	......	......	......	......	270
7	17	45	......	......	......	......	......	......	......	......	......	......	62
8	45	83	14	......	......	......	......	......	......	......	......	......	142
9	65	114	61	60	39	25	10	8	......	5	10	......	397
10	71	79	77	36	27	25	8	......	3	13	10	......	349
Total	496	760	414	289	192	98	46	23	12	48	71	22	2,471

[1] Rept. Ent. U. S. Comm. Agr., 1888, p. 59.

[2] U. S. Dept. Agr., Div. Ent. Bul. 37, n. s., pp. 105-107, 1902.

TABLE III.—*Egg-laying records from 10 plum curculios, College Park, Md., 1902*—Con.

No. of individual.	Date last egg laid.	Date of death of beetles.	Days under observation.	Days on which eggs were laid.	Maximum number of eggs in one day.	Average number of eggs laid per day.
1	Aug. 1	Aug. 2	8	70	15	3.94
2	June 19	June 20	38	32	15	7.34
3	....	May 22	9	....	....	....
4	June 18	June 19	37	36	17	8.44
5	Aug. 1	Aug. 2	8	74	18	5.89
6	June 19	July 10	58	37	15	7.30
7	May 26	May 28	15	10	12	6.20
8	May 30	May 31[1]	19	17	14	8.35
9	July 28	July 31	79	63	19	6.30
10	July 25	July 26	74	57	15	6.12

[1] Escaped.

In Illinois, in 1904, Prof. C. S. Crandall[1] made many interesting observations on 17 female curculios relative to their feeding and egg-laying habits. Some of these are shown in Table IV.

TABLE IV.—*Egg-laying records from 17 plum curculios on apples, Griggsville, Ill., 1904.*

No. of individual.	Eggs laid.	Date of first egg.	Date of last egg.	Date of death of female.	Days under observation.	Days on which eggs were laid.	Maximum number of eggs in 1 day.	Average number of eggs laid per day.
1	84	May 25	July 10	July 24	63	32	9	2.64
2	235	May 26	Sept. 3	Sept. 15	115	84	8	2.80
3	119	...do.....	July 8	July 20	59	37	9	3.21
4	31	...do....	July 17	Sept. 10	111	14	5	2.21
5	12	May 30	June 13	June 16	25	9	2	1.33
6	18	May 25	Aug. 5	Sept. 26	127	12	3	1.50
7	44	May 26	June 22	June 23	32	22	4	2.00
8	....	....	....	....	....	....	....	....
9	19	May 25	July 1	July 26	65	15	2	1.26
10	263	May 26	Aug. 10	Aug. 30	100	69	9	3.81
11	98	June 3	June 25	June 26	35	22	8	4.45
12	....	....	....	....	....	....	....	....
13	197	May 26	Aug. 30	Sept. 6	106	78	6	2.52
14	....	....	....	....	....	....	....	....
15	160	May 26	Aug. 1	Aug. 9	79	59	8	2.71
16	34	May 27	Aug. 17	Sept. 1	102	25	3	1.37
17	252	...do.....	Sept. 9	Sept. 23	123	87	9	2.90
18	249	May 25	Aug. 4	Aug. 10	80	62	9	4.01
19	125	June 2	July 17	July 23	62	42	8	2.98
20	14	June 10	July 18	Aug. 20	87	11	2	1.27
Total	1,954							

The beetles were captured May 23 (one pair May 26) in the act of mating and separately confined in jelly glasses, and were kept indoors on a laboratory table. Fresh apples were supplied at regular intervals. Observations were continued until death of female, as shown.

During the last four or five years numerous egg-laying records have been obtained by the Bureau of Entomology in different parts of the country. These and other life-history studies for the most part have been made under out-of-doors conditions, approaching as closely as possible those which obtained in orchards at the time. (See Pl. XII.)

[1] Ill. Agr. Exp. Sta., Bul. 98, p. 508.

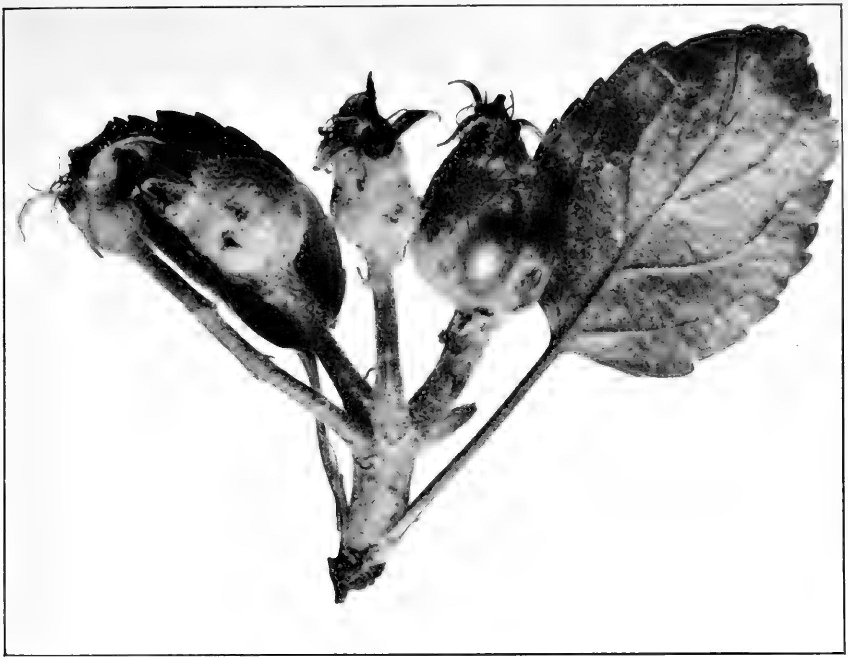


FIG. 1.—EGG AND FEEDING PUNCTURES ON YOUNG APPLES. (ORIGINAL.)

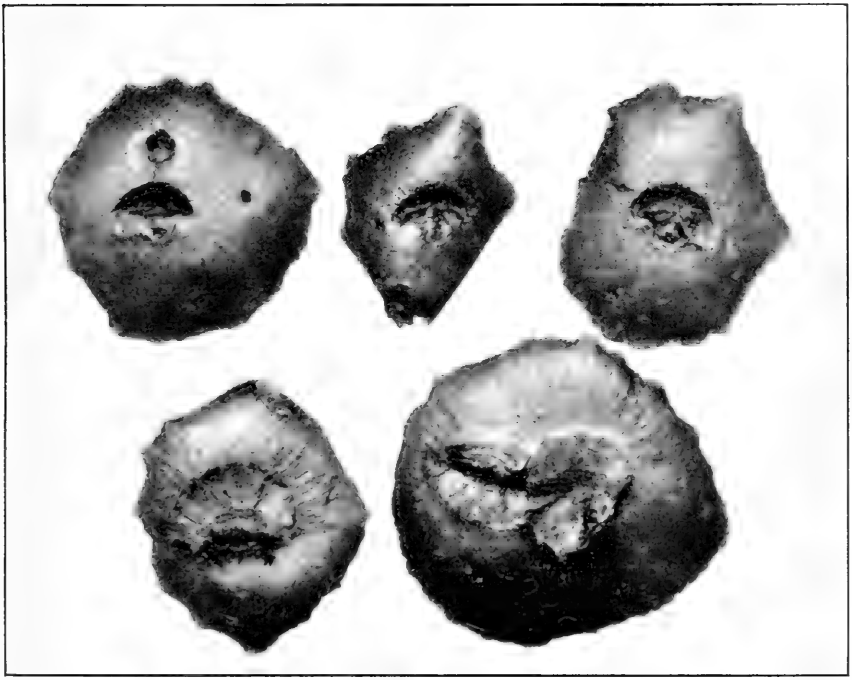


FIG. 2.—EGG PUNCTURES ON APPLE, SOME DAYS OLD. (ORIGINAL.)

WORK OF PLUM CURCULIO ON APPLE.

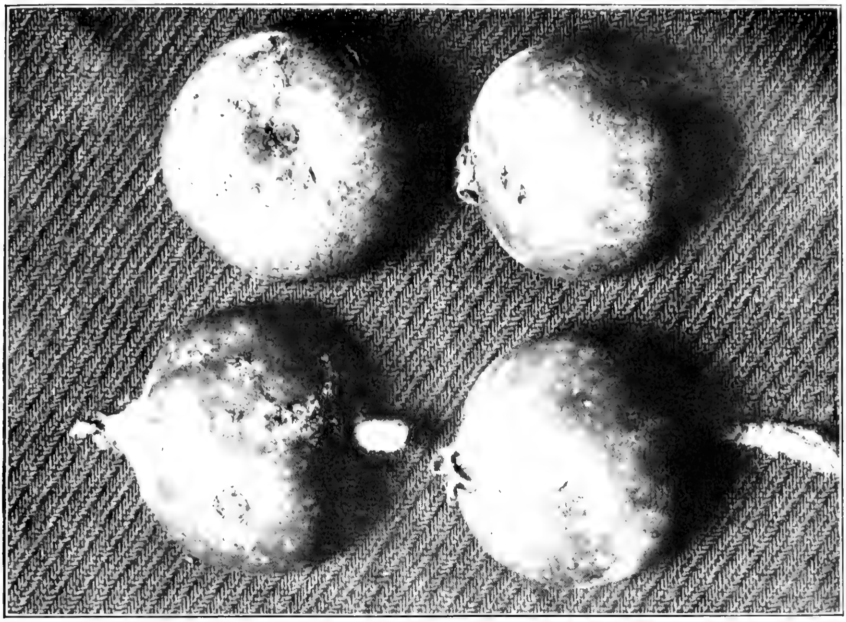


FIG. 1.—YOUNG APPLES, SHOWING SCARS FROM EGG PUNCTURES. (ORIGINAL.)

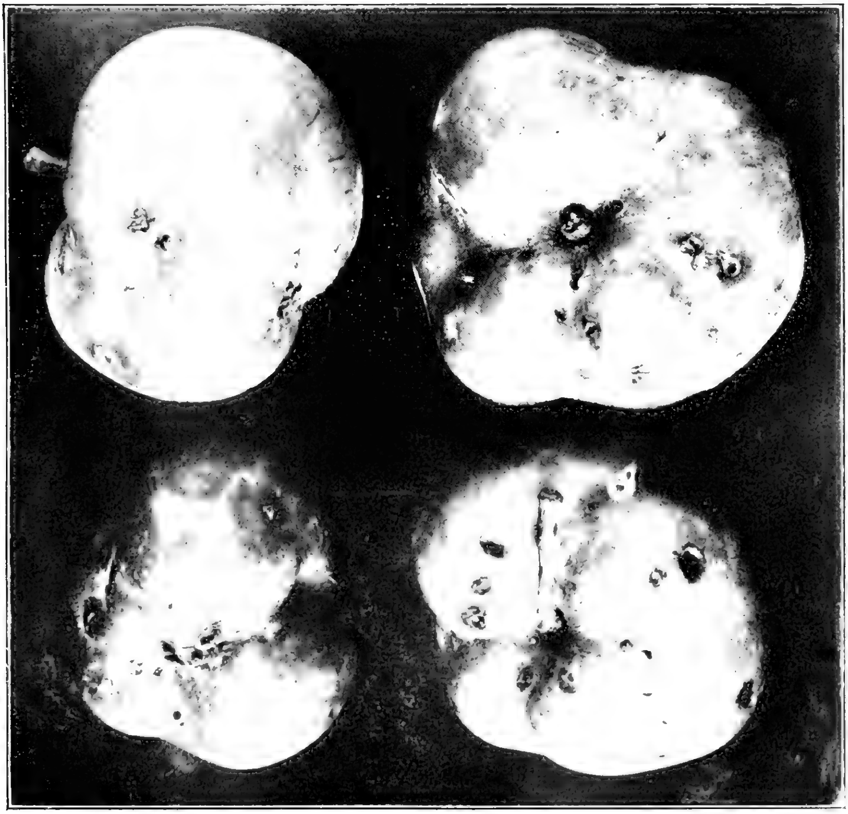
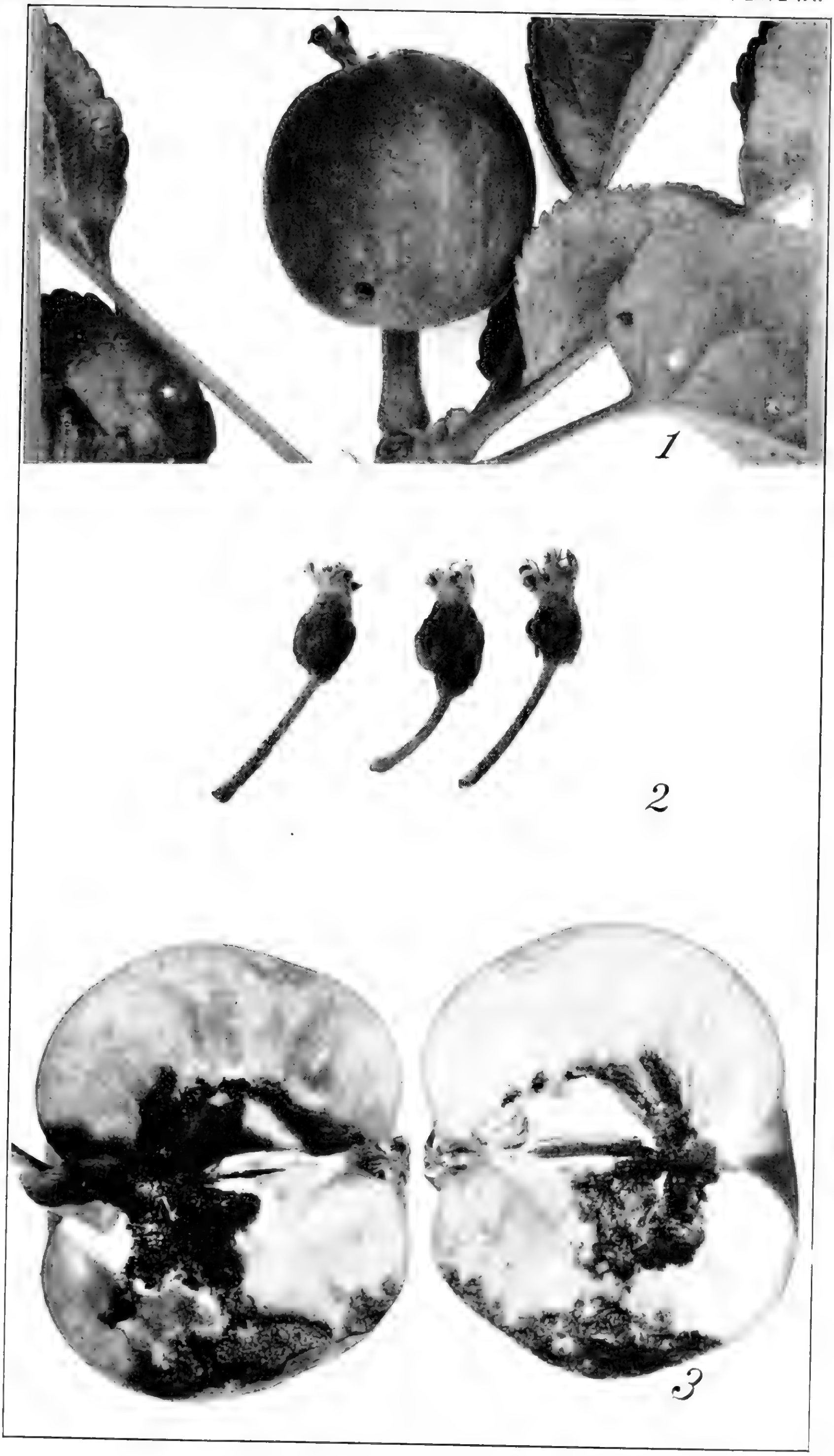


FIG. 2.—RIPE APPLES DEFORMED AND KNOTTY FROM EGG AND FEEDING PUNCTURES OF THE CURCULIO. (ORIGINAL.)

WORK OF PLUM CURCULIO ON APPLE.



WORK OF PLUM CURCULIO ON APPLE.

Fig. 1.—Imperfectly developed apple from tree in which curculio grubs matured. Fig. 2.—Small drop apples in which curculio grubs matured. Fig. 3.—Nearly ripe summer apple from ground, showing extent of feeding by two curculio larvæ. (Original.)

Table V gives by weeks the number of eggs deposited by 8 female curculios, as observed by Mr. Fred Johnson, at Youngstown, N. Y., in 1905. The beetles were taken while mating, June 6, and each pair separately confined in a jelly glass. Observations were made morning and evening, at which times also fresh food was supplied. At date of capture, June 6, no egg punctures were in evidence on fruit in orchards, and the records are doubtless complete.

TABLE V.—*Egg-laying records from 8 plum curculios, Youngstown, N. Y., 1905.*

No. of individual.	Eggs laid each week by each beetle.										
	June 7–13.	June 14–20.	June 21–27.	June 28–July 4.	July 5–11.	July 12–18.	July 19–25.	July 26–Aug. 1.	Aug. 2–8.	Aug. 9–15.	Total.
1	13	12	18	18	8	3	......	......	......	......	72
2	20	21	25	27	28	30	12	6	12	1	182
3	33	30	30	37	48	13	......	......	......	......	191
4	22	28	20	28	20	16	15	7	3	......	159
5	9	28	31	31	34	26	13	4	4	......	180
6	17	20	22	33	27	16	8	6	1	......	150
7	32	31	37	47	34	32	19	14	11	......	257
8	46	16	18	13	5	4	1	......	......	......	103
Total	192	186	201	234	204	140	68	37	31	1	1,294

No. of individual.	Date last egg laid.	Date of death of beetles.	Days under observation.	Days on which eggs were laid.	Maximum number of eggs in one day.	Average number of eggs laid per day.
1	July 12	July 16 ..do.....	39 39	27	5	2.67
2	Aug. 10	Sept. 1 Sept. 10	85 94	54	8	3.37
3	July 14	July 15 July 20	38 43	37	11	5.16
4	Aug. 6	Aug. 22 Sept. 3	76 88	51	11	3.12
5	Aug. 4	Oct. 3 Oct. 12	118 127	49	8	3.67
6	...do.....	Sept. 28 Oct. 4	113 119	45	9	3.33
7	Aug. 8	Aug. 20 Aug. 26	74 80	58	10	4.43
8	July 19	Sept. 23 Sept. 29	108 114	29	9	3.55

In Table VI are given records of observations by Mr. Johnson in 1906 at North East, Pa. Beetles were obtained by jarring, and the pairs in copula placed in individual jelly glasses on May 22. The food was Japan plums.

TABLE VI.—*Egg-laying records from 10 plum curculios, North East, Pa., 1906.*

No. of individual.	Eggs laid each week by each beetle. May 23–29.	May 30–June 5.	June 6–12.	June 13–19.	June 20–26.	June 27–July 3.	July 4–10.	July 11–17.	July 18–24.	July 25–31.	Aug. 1–7.	Total.
1	9	12	14	8	7	1	3	......	......	......	......	54
2	33	16	16	7	......	1	4	6	6	......	1	90
3	33	13	20	8	8	7	4	......	......	......	......	93
4	2	30	17	5	2	4	......	2	......	......	......	62
5	2	35	30	11	7	7	2	3	3	2	......	102
6	2	56	25	22	9	8	......	......	......	......	......	122
7	......	6	16	8	7	7	2	17	8	......	......	71
8	......	1	24	12	6	4	3	16	......	......	......	66
9	......	3	28	12	7	5	......	13	7	3	1	79
10	......	11	7	1	1	4	......	9	12	3	......	48
Total	81	183	197	94	54	48	18	66	36	8	2	787

No. of individual.	Date last egg laid.	Date of death of beetles.	Days under observation.	Days on which eggs were laid.	Maximum number of eggs in one day.	Average number of eggs laid per day.
1	July 10	July 21 ..do.....	60 60	30	6	1.80
2	Aug. 4	June 5[1] Aug. 28[2]	[1] 14 [2] 98	32	16	2.81
3	July 7	July 28 ..do.....	67 67	32	15	2.91
4	July 14	July 13 July 14	52 53	26	6	2.40
5	July 26	Aug. 16 ..do.....	86 86	37	11	2.76
6	July 2	Aug. 13 Aug. 16	83 86	32	16	3.81
7	July 22	June 14[1] July 26[2]	[1] 23 [2] 65	34	4	2.09
8	July 15	July 18[1] July 26[2]	[1] 27 [2] 65	28	7	2.36
9	Aug. 1	Aug. 27 ..do.....	97 97	35	6	2.26
10	July 26	July 28 July 29	67 68	22	5	2.18

[1] Male. [2] Female.

In Table VII are records of eggs laid and of egg punctures by four pairs of beetles kept in the insectary at Washington in 1905.

TABLE VII.—*Egg-laying records from 4 pairs of the plum curculio, Washington, D. C., 1905.*

EGGS LAID EACH WEEK BY EACH BEETLE.

No. of pair.	May 11–17.	May 18–24	May 25–31.	June 1–7.	June 8–14.	June 15–21.	June 22–28.	June 29–July 5.	July 6–12.	July 13–19.	July 20–26.	Total.
1	104	84	109	40	53	50	50	21	17	28	1	557
2	40	56	60	44	29	35	14	......	......	......	......	278
3	48	57	65	37	16	23	17	......	......	......	......	263
4	40	16	8	32	30	......	......	......	......	......	......	126
Total	232	213	242	153	128	108	81	21	17	28	1	1,224

TABLE VII.—*Egg-laying records from 4 pairs of the plum curculio, Washington, D. C., 1905*—Continued.

EGG PUNCTURES MADE EACH WEEK BY EACH BEETLE.

No. of pair.	May 11-17.	May 18-24.	May 25-31.	June 1-7.	June 8-14.	June 15-21.	June 22-28.	June 29-July 5.	July 6-12.	July 13-19.	July 20-26.	Total.
1	112	88	110	48	51	59	67	26	19	34	2	616
2	77	54	70	52	41	44	12	......	......	......	......	350
3	61	65	61	39	16	25	22	......	......	......	......	289
4	51	11	13	28	28	......	......	......	......	......	......	131
Total	301	218	254	167	136	128	101	26	19	34	2	1,386

No. of pair.	Date last egg laid.	Date of death of beetles.	Days under observation.	Average number of eggs laid per day.
1	July 21	Aug. 28[2]	[2] 110	4.95
2	June 26	July 7[1] ....do.[2]	[1] 57 [2] 57	6.19
3	June 26	July 3[1] July 6[2]	[1] 54 [2] 57	4.60
4	June 10	June 18[1] ....do.[2]	[1] 39 [2] 39	3.23

[1] Male. [2] Female.

The beetles were captured at Arundel, Md., on the 9th of May by jarring plum trees. All caught were inclosed together under a bell jar until May 11, when the pairs were separated and placed in individual jars. From three to five fresh plums were added at intervals of one to four days, and those taken out were carefully examined. After about June 10 apples and plums were used as most convenient.

The insects were kept under a temperature considerably higher than out of doors, namely, in the insectary building. The prolificacy of these individuals is not greater on the whole than in the case of those observed at College Park (Table III), but the death of pairs 2, 3, and 4 was evidently hastened beyond what would occur under normal conditions.

In every case more egg punctures were made than oviposited in, though the difference in the case of pairs 3 and 4 is less than with pairs 1 and 2.

In the curculio egg record on peach, Myrtle, Ga., 1906 (Table VIII), the beetles were captured by jarring, April 5, and taken in copulation some hours later. Each pair was separately confined in a jar and supplied with peaches until July 25. As all peaches had been gathered from the trees by this date, foliage was supplied subsequently, which fact no doubt hastened their death, as most individuals died within a few days.

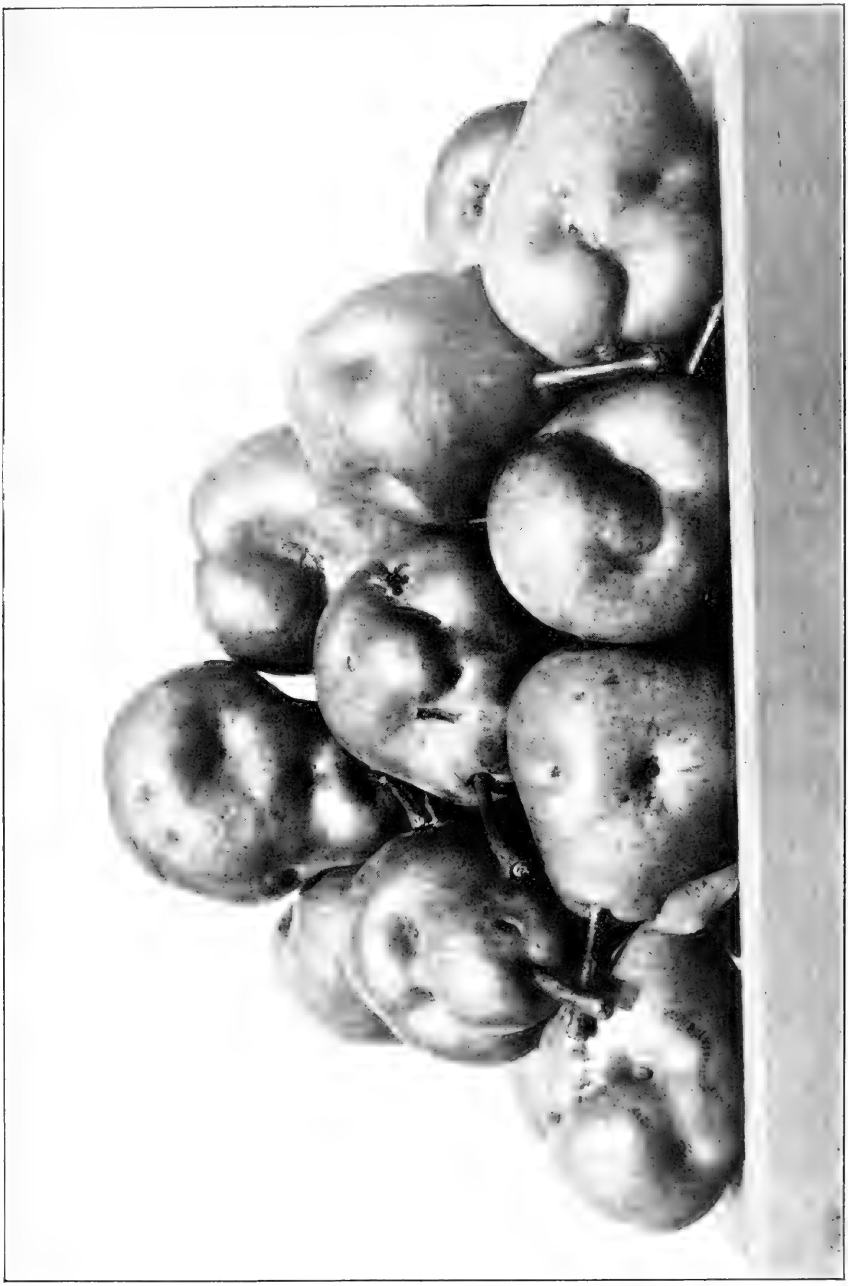
TABLE VIII.—*Egg-laying records from 9 plum curculios, Myrtle, Ga., 1906.*

No. of individual.	Eggs laid each week by each beetle.															Total.
	Apr. 6-12.	Apr. 13-19.	Apr. 20-26.	Apr. 27-May 3.	May 4-10.	May 11-17.	May 18-24.	May 25-31.	June 1-6.	June 7-13.	June 14-20.	June 21-27.	June 28-July 4.	July 5-11.	July 12-18.	July 19-25.	
1	4	4	3	25	6	5	1	6	17	4	1	14	10	....	....	....	100
2	3	3	2	6	3	....	....	....	....	....	....	....	....	....	....	....	17
3	11	13	10	38	20	24	13	11	2	2	2	8	....	....	....	....	154
4	4	3	4	17	....	13	9	4	6	....	....	....	....	....	....	....	60
5	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1
6	18	6	4	22	8	11	5	5	5	3	2	8	....	....	....	....	97
7	4	8	7	13	4	....	....	4	3	....	....	....	....	....	....	....	43
8	12	13	5	25	3	7	....	....	....	....	....	....	....	....	....	....	65
9	2	11	6	30	6	23	20	10	....	9	5	10	3	1	....	15	151
Total	58	62	41	176	50	83	48	40	33	18	10	40	13	1	0	15	688

No. of individual.	Date last egg laid.	Date of death of beetles.	Days under observation.	Average number of eggs laid per day.
1	July 4	May 18 [1] July 30 [2]	[1] 43 [2] 116	3.57
2	May 7	July 29 [1] June 5 [2]	[1] 115 [2] 61	1.55
3	June 22	Aug. 1 [1] June 26 [2]	[1] 118 [2] 82	5.31
4	June 6	July 24 [1] July 26 [2]	[1] 110 [2] 112	3.53
5	....	July 20 [1] ([2])	[1] 106 ([2])	1.00
6	June 22	July 18 [1] Aug. 9 [2]	[1] 104 [2] 126	4.04
7	June 1	June 2 [1] June 26 [2]	[1] 58 [2] 82	2.26
8	May 16	June 18 [1] ..do [2]....	[1] 74 [2] 74	3.82
9	July 25	Aug. 10 [1] Aug. 11 [2]	[1] 127 [2] 128	5.81

[1] Male. [2] Female.

Comprehensive records were obtained at Siloam Springs, Ark., during the season of 1908 (see Table IX). Curculios were jarred from plum trees April 17 and the same day 30 pairs were selected and separately confined in jars. The beetles were given fresh plums daily as long as plums were available, after which apples were used. Observations were made daily.



INJURY BY PLUM CURCULIO TO PEARS.

Knotty and deformed ripe pears resulting from egg and feeding punctures. (Original.)

PLUM CURCULIO INJURY TO CHERRIES. CHERRIES CUT OPEN, SHOWING THE GRUB AND ITS WORK. (ORIGINAL.)

Table IX.—*Egg-laying records from 30 plum curculios, Siloam Springs, Ark., 1908.*

No. of individual.	Number of eggs laid each week by each beetle.																	Total.
	Apr. 22–28.	Apr. 29–May 5.	May 6–12.	May 13–19.	May 20–26.	May 27–June 2.	June 3–9.	June 10–16.	June 17–23.	June 24–30.	July 1–7.	July 8–14.	July 15–21.	July 22–28.	July 29–Aug. 4.	Aug. 5–11.	Aug. 12–19.	
1	12	16	16	31	22	18	16	25	29	12	6	8	2					213
2	15	18	17	38	40	37	27	16	31	23	13	5		1				281
3	15	19	13	44	41	35	44	33	29	21	21	14	29	11	9	7	3	388
4	15	7	7	11	12	4	13	6	14	8	11	2	3					113
5	18	13	16	30														77
6	12	7	12	40	45	42	37	23	25	20	14	18	7	6	1			309
7	12	15	16	26	27	20	27	22	23	14	16	11	4	8	4			245
8		6	7	6	10	17	14	6										66
9	2	9	12	9	9	7	11											59
10	15	20	17	34	24	22	26	26	35	14	21	14						268
11	5	8	11	15	13	6	7	2	1	6	4			2	3			83
12	12	18	21	31	24	19	13	7	8	2								155
13	4	4	11	19	14	19	16	11	13	8	9	1	3					132
14	7	5	5	18	12	11	12	12	26									108
15	16	9	5	19	19	19	16	6	9	2								120
16	2	5	9	21	18	13	13	8	7	4	3	2			4			109
17	8	18	14	31	18	28	26	11	30	10	6	12	2	5	3	2		224
18	10	2	6	25	45	23												111
19	1			3														4
20																		0
21	10	13	12	23	24	20	34	18	30	13	11	13	19	11	3	5	2	261
22	9																	9
23	11	19	20	29	38	43	46	22	12	8	10	7	1	2				268
24	7	2	6	7	9	2												33
25	6	17	15	23	14	13	12	13	7				1					121
26	4	12	19	38	48	48	38	31	17	6	13	8	10	2	2		10	306
27		20	19	41	37	25	36	24	29	14	9	8		1	10			273
28	10			7	9	6					1	1						34
29	10	12	17	24	19	16	19											117
30	6	6	20	30	28	32	33	28	24	10	9	9	2					237
Total	254	300	343	673	619	545	536	350	399	195	177	133	83	49	39	14	15	4,724

No. of individual.	Date last egg laid.	Date of death of beetles.	Days under observation.	Days on which eggs were laid.	Maximum number of eggs in one day.	Average number of eggs per day.
1	July 18	Oct. 8 Oct. 21	170 183	68	11	3.13
2	July 23			72	10	3.90
3	Aug. 16			99	12	3.92
4	July 17			57	10	1.98
5	May 18			21	10	3.66
6	July 30			78	12	3.96
7	Aug. 4			83	8	2.95
8	June 12	July 17[2]	[2] 86	30	5	2.20
9	June 8	Sept. 11[1]	[1] 142	31	5	1.90
10	July 13	July 14[2]	[2] 83	75	8	3.57
11	July 31			45	5	1.84
12	June 24	June 28[1] June 29[2]	[1] 67 [2] 68	53	7	2.92
13	July 18			60	8	2.20
14	June 23	June 28[2]	[2] 67	48	5	2.25
15	June 26	June 29[2]	[2] 68	53	5	2.26
16	Aug. 4			50	5	2.18
17	Aug. 6			69	7	3.25
18	June 2			28	10	3.97
19	May 17			2	3	2.00
20				0	0	
21	Aug. 13			92	8	2.84
22	Apr. 26	Aug. 31 Sept. 1	131 132	3	4	3.00
23	July 27	Sept 7 Oct. 6	138 168	76	10	3.52
24	May 28			21	3	1.57
25	July 17			46	5	2.63
26	Aug. 19	Aug. 30	130	78	12	3.92
27	Aug. 4			77	12	3.54
28	July 14			19	6	1.79
29	June 8			42	6	2.78
30	July 21			73	9	3.24

[1] Male. [2] Female.

In Table X is presented the egg-laying record of 18 beetles, as obtained by Mr. Hammar, at Douglas, Mich., during 1910. The beetles were confined June 7, and the last egg was obtained on July 24. The period of oviposition is noticeably shorter than in several other records presented.

TABLE X.—*Egg-laying record of 18 plum curculios, Douglas, Mich., 1910.*

No. of individual.	Eggs laid each week by each beetle.							Total.
	June 7-13.	June 14-20.	June 21-27.	June 28-July 4.	July 5-11.	July 12-18.	July 19-26.	
1	14	23	29	15				81
2	17	29	35	60	47	13		201
3	11	27	13	6				57
4	4	13	22	24	8	3		74
5	6	9	3	11	15	37	9	90
6		9	37	16				62
7		21	13	23	16	12		85
8	9	16	6	18	8	7		64
9	4	23	32	36	17			112
10	7	21	10	24	27	17	4	110
11		18	26	34	5			83
12		19	20	18				57
13		22	3					25
14		9	12		4			25
15			12	19				31
16			19	58	6			83
17			8	12	6			26
18			29	49	70			148
Total	72	259	329	423	229	89	13	1,414

No. of individual.	Date last egg laid.	Date of death of beetles.	Days under observation.	Days on which eggs were laid.	Maximum number of eggs in one day.	Average number of eggs per day.
1	June 29	July 11 Aug. 15	34 69	16	11	5.06
2	July 13	July 18	41	34	11	5.91
3	June 30	Aug. 22 Sept. 5	76 90	14	10	4.07
4	July 13	July 13 July 30	36 53	22	7	3.36
5	July 24	July 29	52	26	10	3.46
6	July 1	July 5[1]	28	15	10	4.13
7	July 16		0	28	6	3.03
8	July 14	Aug. 1[1]	55	21	6	3.05
9	July 6	..do....	55	22	11	5.09
10	July 20		0	29	9	3.79
11	July 5	July 6	29	16	10	5.19
12	July 1	July 3	26	13	10	4.38
13	June 25	July 31	54	5	9	5.00
14	July 6	July 18[1]	41	9	4	2.78
15	July 3		0	9	4	3.44
16	July 5	July 6	29	12	18	6.92
17	July 8	July 13	36	10	4	2.60
18	July 11	July 12 July 14	35 37	19	14	7.79

[1] Escaped.

All of the above records, with the exception of those from Illinois, are brought together in Table XI. A total of 12,602 eggs is shown from the 7 localities. At College Park, Md., the maximum number of eggs deposited was 426 and the minimum 62, with an average of 274.55 eggs per individual. At Youngstown, N. Y., the range is from 257 for the maximum to 72 for the minimum, with an average of 161.75. At North East, Pa., 122 was the greatest number of eggs deposited by an individual and 48 the lowest, with the average only 78.70. At Washington, D. C., under laboratory conditions the maximum number of eggs laid by a single curculio was 557, the highest of all records for this insect, and the lowest 126, averaging for the 4 individuals under observation 306. At Myrtle, Ga., the maximum was 154 and the minimum 1, although this latter record should perhaps be disregarded; the average was 76.44 eggs per female. The records at Siloam Springs, Ark., include a large number of eggs, namely 4,724, from 29 pairs, one of the beetles confined failing entirely to oviposit. The maximum number of eggs by 1 female was 388 and the minimum 4, giving an average for all pairs of 162.76 eggs. At Douglas, Mich., the greatest number deposited by a single female was 201, and the lowest 25, with an average for the 18 individuals of 78.56 eggs.

In comparing the number of eggs deposited by the different individuals for the respective localities and the averages of all beetles for a given locality, great variation is to be seen. Certain females, perhaps sickly or otherwise abnormal, deposited very few eggs, although feeding freely. Others oviposited assiduously throughout their existence. The final average number of eggs per female for all localities is 144.85, ranging from 1 to 557 eggs. Although the oviposition period is greatly extended, yet the bulk of the eggs is deposited rather early in the season. As shown under the heading of percentages of eggs deposited by the second, fourth, sixth, and eighth weeks, the proportion deposited by a given time varies much in the different localities. There is, however, a general agreement that the great majority of the eggs have been placed by the end of eight weeks. The averages of all localities, shown at close of Table XI, in view of the considerable number of observations doubtless indicate about the rate of oviposition which may be expected in orchards. Approximately one-fourth of the total eggs are laid during the first two weeks, one-half during the first month, three-fourths within six weeks, and 88 per cent of the total within eight weeks after fruit is of size to be usable for oviposition purposes.

TABLE XI.—*Combined weekly egg-laying records of all beetles of the plum curculio for each locality and percentage of eggs deposited within two, four, six, and eight weeks from confinement.*

Localities.	Number of beetles ovipositing.	Total number of eggs laid each week by all beetles of the respective localities.									Total number of eggs.
		First week.	Second week.	Third week.	Fourth week.	Fifth week.	Sixth week.	Seventh week.	Eighth week.	For remainder of period.	
College Park, Md.	9	496	760	414	289	192	98	46	23	153	2,471
Youngstown, N. Y	8	192	186	201	234	204	140	68	37	32	1,294
North East, Pa.	10	81	183	197	94	54	48	18	66	46	787
Washington, D. C	4	232	213	242	153	128	108	81	21	46	1,224
Myrtle, Ga	9	58	62	41	176	50	83	48	40	130	688
Siloam Springs, Ark	29	254	300	343	673	619	545	536	350	1,104	4,724
Douglas, Mich	18	72	259	329	423	229	89	13	......	....	1,414
Total	......	1,385	1,963	1,767	2,042	1,476	1,111	810	537	1,511	12,602

Localities.	Maximum number of eggs per individual.	Minimum number of eggs per individual.	Average number of eggs per individual.	Percentages of total eggs deposited by end of—			
				Second week.	Fourth week.	Sixth week.	Eighth week.
College Park, Md	436	62	274.55	50.82	79.27	91.01	93.40
Youngstown, N. Y	257	72	161.75	29.21	62.82	89.41	97.52
North East, Pa.	122	48	78.70	33.54	70.52	83.48	94.15
Washington, D. C	557	126	306.00	36.35	68.62	87.90	96.24
Myrtle, Ga	154	1	76.44	17.44	48.98	68.31	81.10
Siloam Springs, Ark	388	4	162.76	11.71	33.21	57.83	76.58
Douglas, Mich	201	25	78.56	23.40	76.59	99.08	100.00
Averages for all localities combined	....	....	144.85	26.56	55.04	77.32	88.00

LENGTH OF EGG STAGE.

Little exact information as to the period of incubation of eggs of the plum curculio is to be found in the earlier accounts of this insect. Trimble (Insect Enemies of Fruits, p. 29) states that if the weather be cloudy and cool, a week or 10 days is required for the eggs to hatch, but that in very hot weather the young grubs will escape in 4 or 5 days. Riley and Howard state that from 3 to 10 days are required for the egg stage, depending upon the weather. Other writers have given about the same periods. In 1904, in Illinois, Crandall determined the length of time required for hatching of 6 eggs as approximately 4½ days for 4 and 4 days 9 hours for the other two. His observations were made on eggs kept under laboratory conditions.

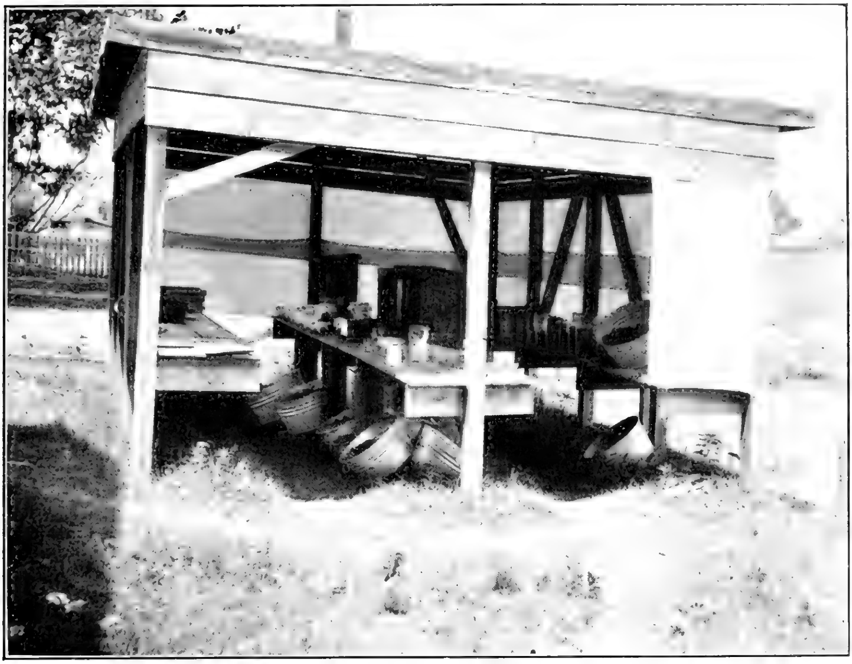


FIG. 1.—OUT-OF-DOOR HOUSE USED IN LIFE-HISTORY WORK. (ORIGINAL.)

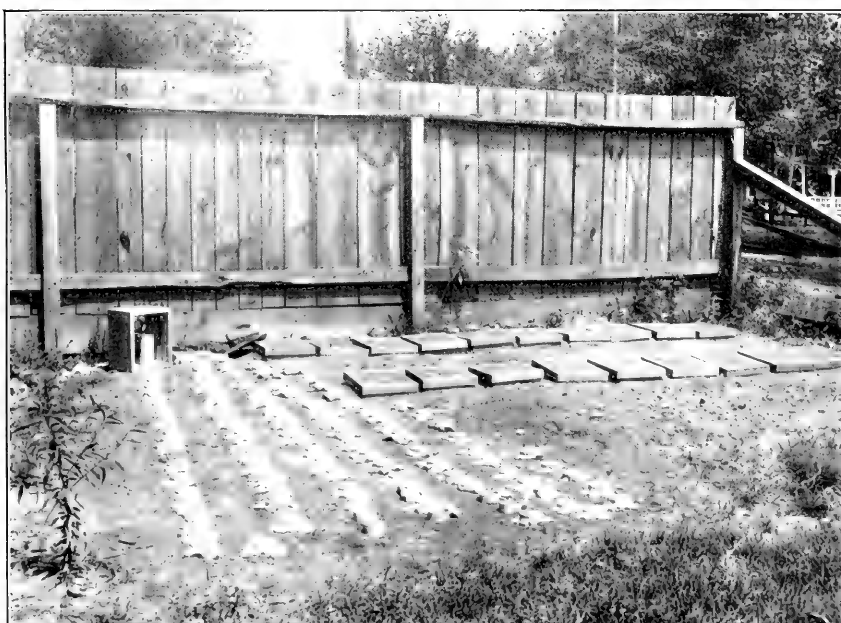


FIG. 2.—SOIL CAGES USED IN OBTAINING DATA ON LIFE OF INSECT IN GROUND. (ORIGINAL.)

METHODS OF STUDY IN PLUM CURCULIO INVESTIGATION, BARNESVILLE, GA.

During the past 3 or 4 years we have been able to secure records on the incubation period for many eggs in different parts of the country.

Observations on the length of the egg stage under out-of-doors conditions were made at Youngstown, N. Y., in 1905, but are not as extended as could be desired. Nevertheless, the following data by Mr. Johnson are of interest: 7 eggs deposited from June 8, a. m., to June 9, a. m., had by June 15 developed as follows:

2 larvæ hatched, but still in egg cavity.
1 larva escaped from eggshell.
1 larva feeding at pit of fruit.
1 larva in short burrow near egg.
2 eggs unhatched.

These figures in a general way would indicate a period for the egg stage of 6 to 7 days.

Forty-six eggs deposited June 15 from 1 to 7 p. m., on June 20 at 2 p. m. were found to have developed as follows:

20 unhatched.
15 larvæ hatched, but still in egg cavity.
11 larvæ in burrows, one-fourth to one-half inch from egg cavity.

This indicates an egg stage of approximately 4½ to 5 days.

Forty-three eggs deposited June 24 were found on June 30, at 6 p. m., to be in the following condition:

6 eggs unhatched.
16 larvæ in burrows, about one-eighth inch from egg cavity.
11 larvæ in egg cavity.
6 larvæ just burrowing out of egg cavity.
4 larvæ feeding at pit.

The egg stage with this lot is from 5 to 7 days.

At Washington, D. C., in 1905, Mr. A. A. Girault made many observations on the length of the egg stage, as shown in Table XII. The eggs were kept in the insectary, and the temperature on the whole averaged considerably higher than at the same time out of doors. The longest period of incubation was 5 days, in the case of 30 eggs deposited on May 18, and the shortest period was 2 days and 15 hours, for a lot of 22 eggs deposited on June 14. The average incubation period, as based on the total number of egg days, is 3.77 days. (See also Table XIII.)

TABLE XII.—*Length of egg stage of the plum curculio, Washington, D. C., 1905.*

Eggs under observation.	Date of deposition.	Approximate length of egg stage.	Total egg days.	Average length of egg stage, by months.
		Days.		*Days.*
1	May 8	3.75	3.75	
40	May 9–10	3.75	150.00	
1	May 9	4.25	4.25	
60	May 10–11	4.00	240.00	
40	May 15	3.75	150.00	
30	May 18	5.00	150.00	
10	May 19	4.75	47.50	
182			745.50	4.10
10	June 7	4.00	40.00	
22	June 14	2.50	55.00	
25	...do	2.75	68.75	
1	June 28	3.50	3.50	
1	...do	3.00	3.00	
59			170.25	2.88
2	July 1	2.75	5.50	
2	July 11	2.75	5.50	
1	...do	2.75	2.75	
1	July 17	2.75	2.75	
6			16.50	2.75

Total number of eggs 247
Total egg days 932.25
Average length of egg stage, days 3.77

Records of 140 eggs, covering the period from April 9 to June 16, 1906, at Myrtle, Ga., are given in Table XIII. Although material under observation was kept in the laboratory, yet temperature conditions in this instance were not essentially different from those obtaining out of doors.

TABLE XIII.—*Length of egg stage of the plum curculio, Myrtle, Ga., 1906.*

Eggs under observation.	Date of deposition.	Approximate length of egg stage.	Total egg days.	Average length of egg stage, by months.
		Days.		*Days.*
1	Apr. 9	2.75	2.75	
1	...do	3.00	3.00	
1	Apr. 11	4.75	4.75	
4	Apr. 12	4.25	17.00	
8	Apr. 15	5.50	44.00	
2	...do	6.75	13.50	
29	Apr. 20	5.25	152.25	
10	...do	5.25	52.50	
38	Apr. 27	4.00	152.00	
11	Apr. 30	3.00	33.00	
105			474.75	4.52
9	May 5	5.75	51.75	
6	May 20	4.50	29.00	
10	May 31	3.25	32.50	
25			113.25	4.53
3	June 7	3.00	9.00	
7	June 16	3.50	24.50	
10			33.50	3.35

Total number of eggs 140
Total egg days 621.50
Average length of egg stage, days 4.44

The shortest period, 2 days 18.5 hours, April 9 to 12, was closely approximated later in the season, June 7. The longest period, 6 days 21.5 hours, occurred April 15 to 22. The average egg period for the entire series is 4.44 days.

In Table XIV are given records of 113 eggs, observed in 1907 at New Richmond, Ohio, on different dates during May and June. The longest egg period was about 6¼ days, on May 18, and the shortest 3 days and 5 hours, on June 20. The average egg period for all lots is 4.92 days.

TABLE XIV.—*Length of egg stage of the plum curculio, New Richmond, Ohio, 1907.*

Eggs under observation.	Date of deposition.	Approximate length of egg stage.	Total egg days.	Average length of egg stage, by months.
		Days.		*Days.*
39	May 18....	6.25	243.75	
31	May 23....	5.00	155.00	
70	....	....	398.75	5.69
23	June 17....	4.00	92.00	
20	June 22....	3.25	65.00	
43	....	....	157.00	3.65

Total number of eggs.. 113
Total egg days.. 555.75
Average length of egg stage, days.. 4.92

Data were secured on the egg period at Siloam Springs, Ark., during late summer from August 15 to 25, the time varying from 3½ to 6 days, the average of the 18 eggs for the period being 4.66 days.

Some egg records made under out-of-doors conditions in the insectary yard, at Washington, 1908, are given in Table XV. The period included from May 7 to 22 was marked by abnormally low temperature, and its effect upon egg development is clearly shown.

TABLE XV.—*Length of egg stage of the plum curculio, Washington, D. C., 1908.*

Eggs under observation.	Date of deposition.	Approximate length of egg stage.	Total egg days.
		Days.	
3	May 7.....	11.00	33.00
1	...do.......	10.75	10.75
4	May 8.....	9.75	39.00
5	...do.......	10.00	50.00
3	May 8-9...	9.50	28.50
1	...do.......	9.75	9.75
2	...do.......	10.50	21.00
1	...do.......	10.75	10.75
5	May 9-10..	8.75	43.75
3	...do.......	9.50	28.50
7	May 10-11.	8.50	59.50
1	...do.......	8.75	8.75
1	May 11....	8.25	8.25
3	May 13....	8.00	24.00
3	May 13-14.	8.00	24.00
1	May 14....	8.00	8.00
1	...do.......	7.75	7.75
45	....	....	415.25

Total number of eggs.. 45
Total egg days.. 415.25
Average length of egg stage..days.. 9.23

The longest egg period was 11 days 2 hours, the shortest 7 days 18 hours, the average length of all lots being 9.23 days. These figures are in wide contrast to those obtained at Washington in 1905, and indeed at all other localities, except for April, at Barnesville, Ga., and the early part of June at Douglas, Mich., in 1910.

Comprehensive data were obtained by Mr. Hammar during 1910, at Douglas, Mich., for June and July, these months averaging somewhat cooler than normal. A total of 944 eggs was observed under out-of-doors conditions, as detailed in Table XVI.

TABLE XVI.—*Length of egg stage of the plum curculio, Douglas, Mich., 1910.*

Eggs under observation.	Date of deposition.	Eggs hatching in specified days from deposition.									Total egg days.
		4	5	6	7	8	9	10	11	12	
11	June 9						1	4	4	2	117
8	June 10						2	6			78
40	June 11					7	33				353
22	June 12					3	19				195
52	June 13				10	40	2				408
46	June 14				36	10					332
54	June 15			20	30	4					362
28	June 16		16	12							152
27	June 17		25	2							137
36	June 18		36								180
11	June 19	3	8								52
50	June 21	12	32	4	2						246
31	June 22	6	18	7							156
33	June 23	10	2	17	4						180
18	June 24	1	5	3	9						110
14	June 25		4	10							80
22	June 26		7	13		2					129
36	June 27		28	7	1						189
38	June 28	3	24	11							198
33	June 29	11	1	21							175
37	June 30		37								185
647	Total										4,014
13	July 1			7	6						84
22	July 3		3	19							129
12	July 4			12							72
21	July 5		5	14	2						123
10	July 6			10							60
18	July 7	14	2	2							78
16	July 8		12	4							84
30	July 9		5	25							175
40	July 10		20	20							220
10	July 11		5		5						60
18	July 12	8		10							92
16	July 14		1	15							95
14	July 15	6			5	3					83
3	July 17			3							18
6	July 18				6						42
8	July 19		8								40
8	July 21		5								25
8	July 22		5								25
10	July 23		5	6							61
5	July 26				3	1		1			39
9	July 28				9						63
297	Total										1,668

Average length of egg stage for June ....days.. 6.20
Average length of egg stage for July ....do.... 5.61
Average length of egg stage for June and July ....do.... 6.02

At Barnesville, Ga., during 1910 the length of the egg stage under out-of-doors conditions was determined for different lots of eggs, during April, May, June, and July, including a total of 445 eggs, all as shown in Table XVII.

TABLE XVII.—*Length of egg stage of the plum curculio, Barnesville, Ga., 1910.*

Eggs under observation	Date of deposition.	Eggs hatching in specified days from deposition.																						Total egg days.
		3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12	12½	13	13½	
33	Apr. 8	...	...	...	...	...	...	...	...	5	7	12	7	1	...	...	1	...	...	...	...	...	...	262.5
43	Apr. 9	...	...	...	...	...	...	...	...	...	9	8	18	1	1	...	...	...	...	...	3	...	3	381.0
93	Apr. 11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	32	44	14	...	3	...	...	1,018.5
169	Total																							1,662.0
10	May 9	...	...	...	...	...	...	...	...	...	1	...	7	2	...	...	...	...	...	...	...	...	...	85.0
14	May 10	...	...	...	...	...	...	...	...	...	5	7	2	...	...	...	...	...	...	...	...	...	...	110.5
19	May 12	...	...	...	...	...	...	...	1	5	10	3	...	...	...	...	...	...	...	...	...	...	...	140.5
2	May 17	...	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	10.0
3	May 18	...	...	...	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	13.5
14	May 19	...	...	4	8	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	62.0
32	May 21	...	...	24	3	5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	134.5
2	May 23	...	...	...	...	1	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	10.5
13	May 25	...	...	...	8	5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	61.0
45	May 26	...	...	17	24	...	4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	198.0
11	May 27	...	...	...	11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	49.5
165	Total																							875.0
1	June 16	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3.5
1	June 17	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3.0
3	June 18	...	1	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	11.5
2	June 20	...	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8.0
1	June 22	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3.5
1	June 23	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4.0
2	June 24	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6.0
3	June 25	...	2	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	11.0
6	June 27	1	3	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	21.5
2	June 28	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	7.0
5	June 29	...	1	...	3	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	22.0
1	June 30	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3.5
28	Total																							104.5
1	July 1	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4.0
2	July 3	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	9.0
2	July 4	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8.0
17	July 6	11	6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	54.0
18	July 7	1	13	4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	64.5
9	July 12	9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	27.0
6	July 14	4	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	19.0
10	July 15	...	5	2	1	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	40.0
10	July 18	...	...	...	6	4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	47.0
8	July 20	...	1	4	2	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	33.5
83	Total																							306.0

Average length of egg stage for April .... days.. 9.83
Average length of egg stage for May .... do.... 5.30
Average length of egg stage for June .... do.... 3.73
Average length of egg stage for July .... do.... 3.68
Average length of egg stage for season .... do.... 6.62

The gradual decrease in the length of the egg stage following the rising temperature is well shown, dropping from the average, 9.83 days, for April to 3.68 days for July. The average for the four months is 6.62 days.

Table XVIII gives a summary of the preceding data. There is seen to be a range of from 2½ days to 13½ days for the different localities, the averages varying from 3.77 to 9.23 days.

TABLE XVIII.—*Length of egg stage of the plum curculio, various localities.*

[From preceding tables.]

Localities and years.	Eggs observed.	Minimum period.	Maximum period.	Average period.	Remarks.
		Days.	*Days.*	*Days.*	
Washington, D. C., 1905	247	2.50	5.00	3.77	Eggs kept in insectary.
Myrtle, Ga., 1906	140	2.75	6.75	4.44	Eggs kept indoors.
New Richmond, Ohio, 1907	113	3.25	6.25	4.92	Do.
Washington, D. C., 1908	45	7.75	11.00	9.23	Eggs kept out of doors.
Siloam Springs, Ark., 1908	18	3.50	6.00	4.66	Eggs kept indoors.
Douglas, Mich., 1910	944	3.00	12.00	6.02	Eggs kept out of doors.
Barnesville, Ga., 1910	445	3.00	13.50	6.62	Do.

THE LARVA.

HABITS OF LARVÆ JUST HATCHED AND COURSE TAKEN IN FRUIT.

After making its escape from the egg, the little curculio larva usually remains for a short period in the egg cavity before boring into the fruit. In a comparatively short time after hatching, however, it has usually buried itself out of sight. Thus a larva hatching at 9.50 a. m. on wild plum remained in the egg cavity until 10.45 a. m., but had disappeared in the flesh by 11 a. m. A larva hatching at 10.46 a. m. was found partly entered at 11.07 a. m. Three larvæ found in their egg cavities at 9.40 a. m. entered the tissues at 10.20, 10.26, and 10.40 a. m., respectively. A larva hatching on apple at 9.30 a. m. did not succeed in getting out of sight in the flesh until 1 p. m., though upon hatching it at once began to burrow. Frequent dissections from fruit of larvæ of known age indicate that within 2 or 3 hours after hatching the fruit has been penetrated.

The course which the larvæ may take in the fruit is somewhat variable, though in general the pit or core is soon reached. Some detailed observations were made on this point by Messrs. Girault and Rosenfeld (Table XIX).

TABLE XIX.—*Course in fruit taken by newly-hatched plum-curculio larvæ.*

Dates of observation.	Kind of fruit.	Location of puncture.	Fruits examined.	Course taken by larvæ in fruit.
Apr. 20	Peach	Base	1	Straight into pit.
May 1	Red June plum	Apex	5	In almost to kernel, then around to basal end of pit.
	do	Basal $\frac{1}{3}$	2	Into side of pit, then around to apical end.
	do	Base		Do.
	do	Apex	1	Straight into pit.
	do	Basal $\frac{1}{3}$	2	Straight in about $\frac{1}{16}$ inch, then around to apical $\frac{1}{3}$ of pit.
2	do	Apex	1	Straight into pit.
	do	Basal $\frac{1}{3}$	1	Do.
	Elberta peach	Center side	1	Do.
	do	do	1	Do.
3	do	do	1	Do.
	do	Base	1	Do.
5	Wild plum	Apex	1	Around under skin for a short distance, then in toward pit; then out toward side of fruit, and in an irregular manner down to about center of side and finally to pit.

TABLE XIX.—*Course in fruit taken by newly-hatched plum-curculio larvæ*—Contd.

Dates of observation.	Kind of fruit.	Location of puncture.	Fruits examined.	Course taken by larvæ in fruit.
May 16	Red June plum	Base	1	In to base of pit.
20	Early Belle peach	Center side	1	In to pit.
26	Wild plum	Basal ⅓	1	Under skin about $\frac{1}{16}$ inch, and around to center of side, then into pit.
27	Peach	Apical ⅓	1	Into pit.
28	do	Basal ⅓	1	Straight in and into pit.
30	do	Apical ½	1	Straight into pit.
30	do	do	1	In straight to apex of pit, and then around to center of other side of fruit.
June 2	do	Apical ⅓	1	Into apical ⅓ of pit, then along pit to center of side.
3	do	Base	1	Into pit; around to center side and into pit.
6	do	Center side	1	Into about center of fruit, then to basal ⅓, and down toward pit.
9	do	do	1	Straight into pit, then along pit to apical ⅓; then down side of pit.

Prof. Crandall has recorded observations on the course taken by larvæ hatching in apples, as follows:

The course taken by the larvæ on emerging from the egg has been traced in a number of apples, and is found to be variable. In one apple examined the bore proceeded straight from an egg cavity near the basin to a point just beneath the skin on the border of the cavity. Another bore was traced in a spiral 2½ times around the fruit. Other bores were found to be tortuous, but in no apple examined did the early bore extend to the core.

LARVAL INSTARS.

The number of molts made by the curculio larva in the course of its growth has not heretofore been determined, probably on account of the difficulty of following the growth of the insect in the fruit. Mr. Hammar, during 1910, in Michigan, determined the number of molts and length of the respective instars for 10 individuals, as shown in the following table:

TABLE XX.—*Larval instars of the plum curculio.*

Individual No.	Dates of molting.					
	Hatched.	First molt.	Second molt.	Third molt.	Left fruit.	Adult.
1	June 28	June 30	July 2	July 5	July 9	Aug. 4
2	June 30	July 2	July 4	July 6	do	Aug. 10
3	do	do	do	July 7	do	Aug. 14
4	July 1	July 3	July 7	July 10	July 15	
5	do	do	July 6	July 9	July 14	Aug. 16
6	July 2	July 4	do	July 8	July 11	Aug. 12
7	do	do	July 7	July 9	July 12	Aug. 15
8	July 4	July 6	July 8	July 11	July 16	Aug. 29
9	July 5	July 7	July 9	July 12	July 18	Aug. 15
10	do	do	do	do	July 17	Aug. 16

TABLE XX.—*Larval instars of the plum curculio*—Continued.

Individual No.	Duration of larval instars.				
	First instar.	Second instar.	Third instar.	Fourth instar in fruit.	Total days to adult.
	Days.	*Days.*	*Days.*	*Days.*	
1	2	2	3	4	37
2	2	2	2	3	41
3	2	2	3	2	45
4	2	4	3	5	....
5	2	3	3	5	46
6	2	2	2	3	41
7	2	3	2	3	44
8	2	2	3	5	56
9	2	2	3	6	41
10	2	2	3	5	42
Totals	20	24	27	41	393
Averages	2.0	2.4	2.7	4.1	39.3

Measurements were made of the width of head-casts of the respective larval molts in the case of one larva, as follows: 0.306 mm., 0.425 mm., 0.595 mm., 1.02 mm.

Head measurements of 19 larvæ at time of leaving the fruit showed a range in width of from 0.935 to 1.071 mm., the average of all being 0.998 mm.

DEATH OF LARVÆ IN FRUIT.

There is much evidence to show that many larvæ die within the fruit, though the cause, or causes, of this mortality is not easy of positive determination. In general, if the fruit falls at the time or shortly after the egg is deposited, this insures favorable conditions for growth of the larvæ. If, however, the fruit remains on the tree, the chances are much more against their successful development, and in the case of some fruits, as the apple and pear, almost entirely so. Prof. Crandall has made interesting observations on the mortality among larvæ in apples. In a lot of 716 fallen apples, 169 curculio larvæ were found, 103 of which, or about 61 per cent, were dead, from causes not established. Most of the larvæ found dead were less than half grown, and many were not more than 2 or 3 days from the egg. Although it is not so stated, it is probably true that these larvæ were killed while the fruit was yet on the trees.

The mortality of larvæ in fruit for the most part results apparently from the crushing effect due to the rapid growth of surrounding tissues; and in the case of stone fruits, as peach and plum, the abundant secretion of gum is perhaps an additional factor. The extent of mortality also varies with the different kinds of fruit.

Thus in the case of apple many observations show that larvæ are almost never able to survive if the fruit remains hanging on the trees for some time after the hatching of the eggs. The eggs for the most part hatch, and the young larvæ begin to feed inward, but before they penetrate far they succumb. Such larvæ show evidence of having been crushed, and often the burrow behind them is well grown over. Apples punctured while still small are most likely to fall; and

after the apple has grown to three-fourths inch or 1 inch in diameter the punctures have much less effect, though the fruit may fall during the thinning process of the tree itself. The egg and feeding punctures, however, usually result in disfigurement of the fruit, often very extensive, as will be discussed under another heading.

During the 4 or 5 years that the curculio has been under investigation no observations have been made wherein the larvæ have survived to maturity in healthy apples on the trees, with the one exception, as observed by Mr. Johnson at North East, Pa., on July 16, 1906, of the occurrence, in a ripening apple on the tree of the Yellow Transparent variety, of three nearly full-grown larvæ. (See Pl. IX, fig. 10.) As in this instance, it is possible that when eggs are deposited in summer varieties as they are beginning to ripen, the resulting larvæ would mostly be able to survive, since the stage of rapid growth of the fruit has passed. On another occasion in this locality Mr. Johnson observed, August 1, 1906, in an orchard of the Baldwin variety, numerous small and highly colored apples on the trees about the size of walnuts, some of which contained full-grown curculio larvæ, and other fruits showed their exit holes. Unquestionably in this instance the normal development of the fruit had been checked from other causes, though it had failed to fall. The condition is not essentially different from that when the fruit drops to the ground.

In interesting contrast to the practically complete death of all larvæ hatching in apples which remain on the trees, and to a large extent of those which do not drop until some days after hatching, is the condition found to obtain when eggs are deposited in confinement in apples removed from the trees. In such cases, as has been observed frequently, a large percentage of the deposited eggs produces mature vigorous larvæ. Figures obtained by Crandall, involving 1,474 eggs deposited in fallen fruit, show that 1,238, or 83.92 per cent, of these resulted in mature larvæ.

In the case of pears, although these are oviposited in freely by the beetles, larvæ appear never able to survive in fruit on the trees, and but rarely on fruit on the ground. Unlike the apple, the young pear, when it falls, tends to dry up, and on account of the stony tissue present becomes very hard. In 50 young fruits of the LeConte and Kieffer pear taken from trees at Myrtle, Ga., May 2, and bearing numerous egg-punctures, no live larvæ were found, none of the punctures was fresh, and all were more or less outgrown. An examination of the egg cavity showed in most cases, however, borings of the young larvæ, and their dead bodies.

In lots of Kieffer pears containing eggs, collected at Myrtle, Ga., April 9 and 20, the eggs were observed to hatch, but larvæ failed to develop. Pears of this same variety collected from the ground April 13 and 20 and May 9 gave no results except from one lot, 4 adults

being reared. Further attempts at rearing from pears in this locality gave no results.

May 21 and 23, 1905, at Washington, D. C., and again May 30, 1905, young Kieffer pears from trees were confined with beetles, and eggs were deposited freely. No larvæ, however, succeeded in developing.

During the course of the season of 1905 many fallen pears were examined by Mr. Johnson at North East, Pa., and he found only a single curculio larva, about one-third grown, feeding in the core of a pear on the ground. No larvæ were found in fruit on the trees.

Observations on plums, wild and cultivated, in many localities show that there is also a high mortality among larvæ where the fruit remains on the tree or if its dropping be materially retarded. Plums punctured while small are more apt to drop than if the fruit is one-third grown or over. This dropping of the smaller fruit and the shedding of the fruit by the tree itself enables the species to more than maintain itself. Larvæ hatching in fruit which does not fall are ordinarily able to penetrate the flesh but a short distance before succumbing, perhaps due to the combined effect of the copious gum exuded and the pressure of the growing tissues. The evidence also is that the egg may be destroyed by the gum exuding at the punctured point, and our notes show the examination of many punctures in which the egg could not be found, or was crushed, the cavity being completely filled with gum. The number of eggs or larvæ missing has been quite too large to be accounted for otherwise. Many plums of the Japanese and Domestica types and of wild native sorts have been examined when taken from the trees and bearing egg punctures, and the conclusion is evident that larvæ are not able to survive during the rapid growing period, and, as in the case of the apple, their successful development depends on the falling of the fruit. After the fruit has become grown, and the ripening process begins, larvæ are more likely to survive, and ripe wormy plums, especially of the cultivated Japanese sorts, are not infrequently to be met with.

The development of the peach, with reference to its availability as a host for the curculio, may be divided into three stages. The first stage includes the time from the beginning of oviposition to near the time when the pits begin to harden, a period of 3 or 4 weeks, during which approximately 75 per cent of the total infestation of the season occurs. The fruit in this stage, though growing rapidly, does not exude gum upon being punctured and readily drops from the tree when infested by curculio larvæ. (See Pl. V, fig. 1.) Probably no fruit infested at this time remains long on the tree. The second stage in the growth of the peach begins when the pits show the first signs of hardening and extends up to the ripening period.

At the beginning of this second stage there is a sudden cessation of both egg laying and feeding, and during the whole time the beetles refrain from puncturing the fruit except in occasional instances. The fruit in this stage exudes gum very copiously when punctured. (See Pl. VI, fig. 2.) Relatively little growth is made while the pit is hardening, but in the few cases in which eggs are laid and hatched at this time the larvæ are killed at an early stage by the flooding of their burrows with gum, the fruit failing to fall from the tree. The third stage includes the ripening period, when the beetles resume oviposition and the larvæ are able to mature normally. It is at this time that all the infestation of ripe fruit occurs, though the number of individuals developing is small in comparison with those in the young fruit which falls off.

Another factor in the mortality of larvæ in drop fruit, as noted by Crandall in apples, is the effect of sunshine. According to this gentleman, no living larvæ could be found in fruit exposed to the sun for a few hours, whereas fruit taken from under the shade of the trees contained a fair proportion of living larvæ. An interesting experiment is quoted, bearing on the matter:

> In one box were placed 200 apples and in another 250, the latter being placed in full exposure to the sun. Later examination of soil in the respective boxes gave for the former 42 pupæ and for the latter 3 only.

As suggested by Prof. Crandall, this points to the advisability of following a method of orchard management which will insure as free access of the sun as possible.

DESERTION OF FRUIT BY UNDERSIZED LARVÆ.

On many occasions it has been noted that larvæ may leave the fruit before reaching maturity and burrow below the soil as for pupation. This premature abandonment of fruit is perhaps often forced by reason of the unfavorable condition of the latter, but in many cases this explanation will not suffice. Fruit in an excellent condition for feeding purposes has been often thus deserted. An unhealthy condition of the larva itself, as from parasitism, might be suspected, but rearings of such individuals indicate that this is not the case. Larvæ have at times been observed to leave fruit, as in a glass jar without soil, and, in the absence of suitable surroundings for pupation, reenter the fruit and there finally pupate. It is doubtful, however, if there is any tendency of larvæ to leave one fruit in search of another, and a faulty instinct seems most likely to account for this behavior. Larvæ emerging from peaches and plums collected throughout the season (p. 62) at Washington, D. C., in 1908, varied in about the following proportion: Large, 45.25 per cent; medium,

39.04 per cent; and small, 15.69 per cent. Adults were never reared from the small larvæ, though the attempt was repeatedly made.

At Barnesville, Ga., during 1910, observations were also made on this point. Among the first larvæ of the season to leave drop fruit was a large number of undersized individuals. Many were not more than one-half normal length, and from this they varied to full size. The proportion of small larvæ was greatest during the first week or ten days after larvæ began leaving the fruit, the proportion becoming less and less until by two weeks after the first larvæ began emerging practically all individuals were of normal size. In Table XXI is shown the proportion of undersized larvæ during the period from May 2 to 21, when they were in evidence.

TABLE XXI.—*Record of undersized and normal larvæ of the plum curculio from drop fruit from 31 peach trees, Barnesville, Ga., 1910.*

Dates.	Larvæ leaving fruit.	Distinctly undersized larvæ.		Dates.	Larvæ leaving fruit.	Distinctly undersized larvæ.	
		Number.	*Per cent.*			*Number.*	*Per cent.*
May 2	49	38	78	May 12	272	22	8
3	68	33	48	13	159	6	4
4	119	48	40	14	86	5	6
5	164	66	40	15	58	2	3
6	175	26	15	16	48	1	2
7	99	26	26	17	38	1	3
8	110	12	11	18	33	0	....
9	357	80	22	19	71	0	....
10	240	29	12	20	102	1	1
11	209	28	23	21	54	1	2

NORMAL EMERGENCE OF LARVÆ FROM FRUIT DURING THE SEASON.

In order to determine over what period and in what abundance larvæ left the fruit and entered the soil for pupation, as bearing on the period for cultivation for the destruction of the pupæ, it was planned in 1908 regularly to collect, at frequent intervals throughout the season, all of that fruit which fell to the ground and to rear and record the larvæ as they emerged from the respective lots of fruit. This work was done during 1908 at Siloam Springs, Ark., using all drop fruit for the season from 120 peach trees; and during the same year at Washington, D. C., by Mr. P. R. Jones, with both peaches and Japan plums, using all of the drop fruit on 10 peach trees, and in addition to the drop fruit from 8 Japan plum trees that from the trees at ripening time was also used.

During 1910 similar data were obtained at Barnesville, Ga., and by Mr. Hammar at Douglas, Mich. In Georgia all of the drop fruit throughout the season from 31 peach trees was regularly collected and larvæ recorded as they came from the respective lots. At picking time the fruit from 12 of the 31 trees was gathered and

larvæ recorded, but for uniformity the estimated number of larvæ from the fruit from the 31 trees is used in the table.

In Michigan the drop and picked fruit from 15 peach trees was used, collections beginning June 30 and continuing to August 27. These records, it is believed, should show the normal seasonal history of the insects in this stage under orchard conditions. Such

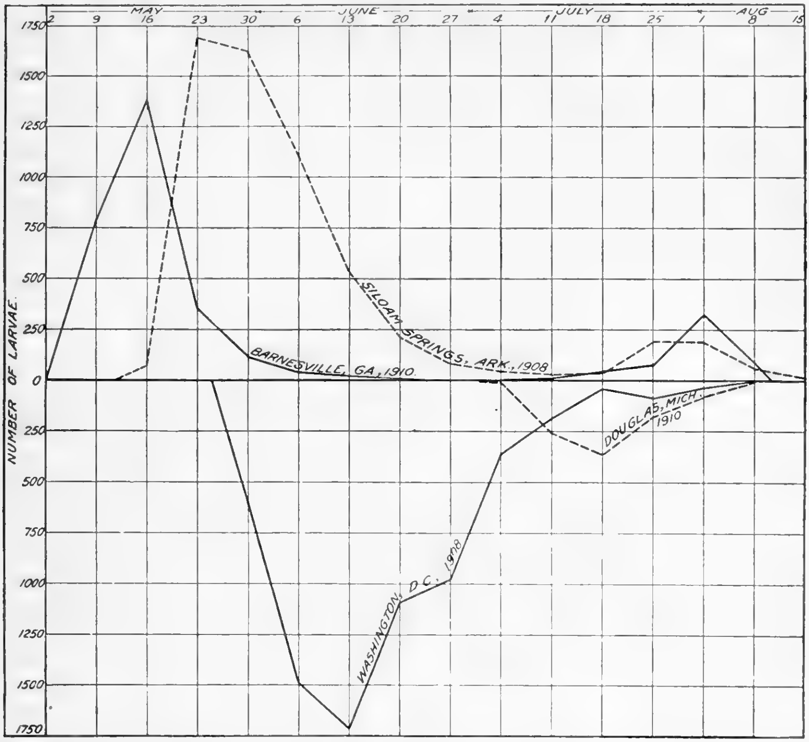


FIG. 20.—Diagram showing normal emergence from fruit of larvæ of plum curculio during season at Siloam Springs, Ark., Barnesville, Ga., Washington, D. C., and Douglas, Mich. (Original.)

records are evidently much more reliable than those which do not take account of all of the fruit for the season.

In Table XXII are shown the totals emerging for each of the four localities by days, as also the number and percentages of larvæ emerging by months.

These same data, summarized by weeks, are shown graphically in figure 20.

TABLE XXII.—*Emergence of plum curculio larvæ throughout the season, from total fruit, in various localities, 1908–1910.*

Dates.	Barnesville, Ga., 1910.			Siloam Springs, Ark., 1908.			Washington, D. C., 1908.			Douglas, Mich., 1910.		
	Total larvæ emerging by days.	Total for each month.	Percentage for each month.	Total larvæ emerging by days.	Total for each month.	Percentage for each month.	Total larvæ emerging by days.	Total for each month.	Percentage for each month.	Total larvæ emerging by days.	Total for each month.	Percentage for each month.
May 2	49											
3	68											
4	119											
5	164											
6	175											
7	99											
8	110											
9	357											
10	240											
11	209											
12	272			6								
13	159			22								
14	86			28								
15	58			18								
16	48			154								
17	38			195								
18	33			177								
19	71			201								
20	102			374								
21	54			300								
22	12			291								
23	22			243								
24	27			166								
25	26			141			50					
26	13			164			45					
27	6			233			187					
28	21			232			318					
29	6			444								
30	11			136			218					
31	10			139			297					
		2,665	81.64		3,664	61.89		1,115	16.92			
June 1	7			154			287					
2	3			159			220					
3	2			219			181					
4	5			169			110					
5	2			140			174					
6	2			140			290					
7	4			84			236					
8	3			82			229					
9	6			104			180					
10	3			33			154					
11	3			45			249					
12				46			377					
13	1			41			172					
14				39			190					
15				27			140					
16				15			296					
17				32			107					
18				34			64					
19				33			127					
20				23			110					
21				5			139					
22				10			182					
23				16			131					
24				16			184					
25				9			76					
26				3			155					
27				9			97					
28				6			68					
29	1			12			25					
30				10			52					
		42	1.28		1,715	28.97		5,002	75.93			
July 1				2			50			2		
2				2			43			2		
3				6			34			4		
4				1			24			32		
5				5			29			37		

TABLE XXII.—*Emergence of plum curculio larvæ throughout the season, from total fruit, in various localities, 1908–1910*—Continued.

Dates.	Barnesville, Ga., 1910.			Siloam Springs, Ark., 1908.			Washington, D. C., 1908.			Douglas, Mich., 1910.		
	Total larvæ emerging by days.	Total for each month.	Percentage for each month.	Total larvæ emerging by days.	Total for each month.	Percentage for each month.	Total larvæ emerging by days.	Total for each month.	Percentage for each moth.	Total larvæ emerging by days.	Total for each month.	Percentage for each month.
July 6	1			9			16			27		
7				5			36			43		
8	4						39			36		
9	1			8			29			41		
10	1						10			35		
11	1			3			11			17		
12										14		
13	2			3			6			91		
14	12			7			8			56		
15	10			8			8			31		
16	14			14			11			19		
17	6			4						140		
18	13			5			10			68		
19	4			8						55		
20	1			3			15			17		
21	3			45			17			8		
22	13			63			12			15		
23	12			38			12			4		
24	30			35			19			15		
25	29			46						22		
26	56			38						34		
27	51			24			15			4		
28	77			29			4			5		
29	35			21			4			7		
30	56			11			3			6		
31	26			24			4			2		
		458	14.02		467	7.89		469	7.12		889	99.33
Aug. 1	29			16			1					
2	5			24								
3	5			6			1					
4	21			8								
5	13			2						3		
6	11			2						1		
7	5			4								
8	5			4						2		
9	5			1								
10				4								
11				1								
12												
13				2								
14												
		99	3.06		74	1.25		2	.03		6	.67
Total	3,264	3,264	100.00	5,920	5,920	100.00	6,588	6,588	100.00	895	895	100.00

In the above table, the Georgia records show a total of 3,264 larvæ leaving the fruit between May 2 and August 9. A large majority of these, 2,665, or 81.64 per cent, issued during May; during June only 42, or 1.28 per cent, issued, while during July, 458, or 14.02 per cent, was secured. August shows a total of 99 larvæ, or 3.06 per cent. At Siloam Springs, Ark., in 1908 a total of 5,920 larvæ issued, the interval covering the period from May 12 to August 13. Larvæ to the number of 3,664, or 61.89, left the fruit during the period from May 12 to 31; while for June, 1,715, or 28.97 per cent, left the fruit, a total for the approximately 7 weeks of 5,379, or 90.86 per cent.

July shows an emergence of 467 larvæ (7.89 per cent) and August 1 to 4, after which no more emerged, 74, or 1.25 per cent.

At Washington, D. C., during 1908, a total of 6,588 larvæ was reared, 1,115 emerging during the last 7 days of May. During June 5,002 larvæ left the fruit, a total for May and June of 6,117, or 92.85 per cent. Only 7.12 per cent of the total larvæ emerged during July, emergence practically ceasing with that month. The Michigan records include only 895 larvæ, of which 889, or 99.33 per cent, left the fruit during July.

The foregoing data, with the additional records by Crandall from Illinois, are shown in Table XXIII with the dates of blooming of peach trees for that year.

The relation of these data to the time of making cultivations is shown on page 176.

Table XXIII.—*Emergence by months of plum-curculio larvæ in different localities.*

Localities.	Approximate date of full blossom of peach trees.	May.		June.		July.		August.		September.		Total.
		Larvæ emerging.	Percentage.	Larvæ emerging.	Percentage.	Larvæ emerging.	Percentage.	Larvæ emerging.	Percentage.	Larvæ emerging.	Percentage.	
Barnesville, Ga.	Mar. 15	2,665	81.64	42	1.28	458	14.02	99	3.06	......	......	3,264
Siloam Springs, Ark.	Mar. 18	3,664	61.89	1,715	28.97	467	7.89	74	1.25	......	......	5,920
Washington, D. C.	Apr. 6	1,115	16.92	5,002	75.93	469	7.12	2	.03	......	......	6,588
Douglas, Mich.	Apr. 20	......	......	......	......	889	99.33	6	.67	......	......	895
Griggsville, Ill.	May 10[1]	......	......	254	20.52	662	53.47	272	21.97	50	4.04	1,238

[1] Apple.

MANNER OF LEAVING THE FRUIT AND ENTERING THE SOIL.

Upon completing its growth, the larva leaves the fruit in which it has been feeding, and soon makes its way beneath the soil. Fruit lying upon the ground will usually show, when examined, the small exit hole of the grub, mostly along the lower side where the fruit was in contact with the earth. An examination of 200 infested drop peaches showed these exit holes to be located as follows: Apex, 8; apical third, 64; center of side, 66; basal third, 46; base, 16. This shows that 88 per cent of the exit holes are along sides as against the ends, which is perhaps proportionate to the respective areas. In deserting the fruit on the trees, as peaches and cherries, the larva must fall, and this is probably not injurious to it. Once upon the ground, the instinct is immediately to get below the soil. The time occupied in accomplishing this will vary according to character of soil, whether cultivated or not, and the presence of crevices, etc. At this time especially the larvæ are exposed to predaceous insects, par-

ticularly ants, and numerous larvæ perish from their attack. Many larvæ have been timed by the watch, and the interval occupied until out of sight below the soil has varied from about one-half to 50 minutes.

Table XXIV includes observations made in Georgia and in Washington, D. C., both in the orchard and in small jars in the laboratory. It will be noted that more time is usually spent in searching for a suitable place to enter than in actually working below the surface. The average time on the ground and until beneath the soil, in the data given, is about 12 minutes. A larger series of observations would probably change these figures somewhat.

TABLE XXIV.—*Time occupied by larvæ of the plum curculio in entering soil.*

Localities.	Larva No.	Time on soil.	Began to enter.	Beneath soil.	Time occupied.	Kind of soil.
Myrtle, Ga.:					*Minutes.*	
Laboratory	1	10.00	10.06	10.11½	11½	Fresh sandy loam soil in glass jar, gently packed.
	2	2.07	2.15	2.21	14	Do.
	3	10.21	10.21½	10.22	1	Do.
	4	9.13	9.14	9.15	2	Do.
	5	4.08	4.10½	4.12	4	Do.
	6	9.59	10.00	10.03	4	Do.
	7	9.43	9.44	9.49	6	Do.
	8	10.22	10.23	10.24	2	Do.
	9	10.22	10.25	10.30	8	Do.
	10	4.16	4.18	4.26	10	Do.
In orchard	11	5.22	....	5.23	1	Dry sandy soil under peach tree.
	12	5.22	....	5.26	4	Do.
	13	5.22	....	5.27	5	Do.
	14	5.22	....	5.31	9	Do.
	15	5.22	....	5.34	12	Do.
	16	5.22	....	5.39	17	Do.
	17	5.22	....	5.49	27	Do.
Washington, D. C.:						
Insectary	18	1.26½	1.29	1.41	14½	Sandy garden soil in box, moderately compacted.
	19	1.30	1.59	2.19	49	Do.
	20	1.48	2.40	3.23	35	Do.
	21	2.23	2.36	2.40	17	Do.
	22	2.10	2.37	2.42	32	Do.
	23	2.44	2.46	2.47	3	Do.
	24	2.23	2.41	2.44	21	Do.
In orchard	25	2.55	2.55	3.11	16	Clay loam, well cultivated. Larvæ placed under plum tree.
	26	2.55	2.56	3.00	5	Do.
	27	3.33	3.34	3.36	3	Do.
	28	3.03	3.15	3.18	15	Do.
	29	3.20	3.22	3.25	5	Do.
	30	3.14½	3.15½	3.16½	2	Do.

TIME SPENT IN THE FRUIT (EGG AND LARVAL STAGES COMBINED).

In 1904 Prof. Crandall determined, for Illinois, the time spent in apples (combined egg and larval stages) for 1,238 individuals. A few larvæ left the fruit within 12 and 13 days from deposition of egg, and some spent an unusually long time in the fruit. The great majority, however, developed and left the fruit in about the average time. Table XXV gives his emergence records by months, and also the average period per individual within fruit for that month.

TABLE XXV.—*Length of time spent in fruit by plum curculio, Illinois, 1904.*

Months.	Total number of larvæ emerging.	Percentage of whole.	Average time in fruit.
			Days.
June	254	20.52	18.07
July	662	53.47	19.15
August	272	21.97	21.55
September	50	4.04	26.00
Total	1,238	100.00	....

The average time for egg and larva in the fruit for the whole season was about 20 days.

In Table XXVI are given records of a few observations from Youngstown, N. Y. (1905), and North East, Pa. (1906).

TABLE XXVI.—*Length of time spent in fruit by the plum curculio (egg and larval stages combined), Youngstown, N. Y., 1905, and North East, Pa., 1906.*

Localities.	Eggs deposited.	Date of deposition.	Larvæ emerged. Number.	Larvæ emerged. Date.	Approximate time in fruit.	Total number of larvæ developed.	Total number of egg and larval days.	Average number of days in fruit.
					Days.			
Youngstown, N. Y.	43	June 24, 1905	8	July 10, 1905	16.00	17	303.25	17.83
			1	July 12, 1905	18.25			
			3	July 13, 1905	19.00			
			5	July 14, 1905	20.00			
North East, Pa.	(?)	June 13, 1906	5	July 9, 1906	25.50	7	169.50	24.21
			2	July 3, 1906	21.00			
		June 14, 1906	6	July 5, 1906	20.75	6	124.50	20.75
		June 15, 1906	4	July 3, 1906	18.00	4	72.00	18.00
Total	....	....	......	....	....	34	669.25	......

Average time spent in fruit during June for both localities .... days.. 19.68

During 1905, at the insectary in Washington, data were obtained on the length of time spent in the egg and larval stages in the fruit for miscellaneous lots during May and June. As in the case of egg-hatching records, these were obtained under the same conditions in the insectary, where the temperature was higher than normal. These records are given in Table XXVII.

TABLE XXVII.—*Length of time spent by the plum curculio in fruit (egg and larval stages combined), Washington, D. C., 1905.*

Eggs deposited.	Date of deposition.	Larvæ emerged. Number.	Larvæ emerged. Date.	Approximate time in fruit.	Total number of larvæ developed.	Total number of egg and larval days.	Average number of days in fruit.	Host fruit.
				Days.				
(?)	May 12	2	May 23	11.50	15	211.50	14.10	Plum.
		2	May 24	12.50				
		2	May 25	13.50				
		3	May 26	14.50				
		6	May 27	15.50				
7	May 15	2	May 30	15.00	7	112.00	16.00	Do.
		3	May 31	16.00				
		2	June 1	17.00				
1	May 16	1	June 2	16.75	1	16.75	16.75	Do.
	May 16–17	3	June 3	17.50	3	52.50	17.50	Do.
	May 16–18	1	June 1	14.75	30	523.75	17.46	(?)
		14	June 2	16.00				
		15	June 3–6	19.00				
9	May 18–19	3	June 3	15.50	5	85.50	17.10	Plum.
		2	June 7	19.50				Do.
5	May 19	5	June 6	17.75	5	88.75	17.75	Do.
(?)	May 20–23	16	June 5–6	15.00	25	388.25	15.53	Do.
		7	June 7	16.25				
		2	June 8	17.25				
(?)	May 23–25	6	June 6	12.75	38	554.75	14.60	Apple.
		21	June 7	14.00				
		11	June 10	16.75				
16	May 23–24	2	June 6	13.50	10	157.00	15.70	Plum.
		2	June 7	14.75				
		6	June 9	16.75				
14	May 24–25	1	June 7	13.50	12	188.00	15.67	Do.
		7	June 9	15.50				
		4	June 10	16.50				
9	May 25–26	5	...do.....	15.50	5	77.50	15.50	Apple.
9	May 25–27	5	June 7	13.00	7	93.00	13.29	Plum.
		2	June 8	14.00				
	Total and average				163	2,549.25	15.64	
15	June 6–7	4	June 26	19.25	15	308.75	20.58	Apple.
		8	June 27	20.25				
		3	June 30	23.25				
	June 9–10	4	June 24	14.25	4	57.00	14.25	Plum.
7	June 10	2	June 21	10.50	2	21.00	10.50	Do.
24	June 11–13	1	June 25	12.25	21	374.25	17.82	Apple.
		1	June 26	13.75				
		4	June 29	16.75				
		15	July 1	18.75				
13	June 10–13	9	June 27	15.00	11	166.00	15.09	Do.
		2	June 28	15.50				
20	June 14	10	June 29	14.75	18	273.50	15.19	Do.
		8	June 30	15.75				
10	June 14–15	6	June 28	13.25	9	129.00	14.33	Do.
		3	July 1	16.50				
2	June 17	2	July 4	17.00	2	34.00	17.00	Do.
	Total and average				82	1,363.50	16.62	
	Total for season				245	3,912.75	....	

Average time spent in fruit for season, days 15.99

The records show a range for combined egg and larval stages of from $10\frac{1}{2}$ to $23\frac{1}{4}$ days, with the average for the season of 15.99 days. The total number of larvæ under observation was 245 and the sum of egg and larval days was 3,912.75.

Observations made at Myrtle, Ga., during 1906, on miscellaneous lots of eggs and larvæ in peaches, during April, May, and June, are detailed in Table XXVIII.

TABLE XXVIII.—*Length of time spent in fruit by the plum curculio (egg and larval stages combined), Myrtle, Ga., 1906.*

Eggs deposited.	Date of egg deposition.	Mature larvæ developed.	Larvæ leaving fruit in specified days from deposition of eggs. 11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total egg and larval days in fruit.
9	Apr. 19	4	...	...	...	3	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
21	Apr. 21	4	...	...	...	...	...	...	2	2	...	...	...	...	...	...	...	...	...	...	...	...	...
(?)	Apr. 23	3	...	...	...	1	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...
(?)	Apr. 26	7	...	...	3	...	...	1	2	...	...	1	...	...	...	...	...	...	...	...	...	...	...
(?)	Apr. 27	5	...	...	...	...	...	...	...	...	3	...	...	1	...	...	...	...	...	...	1	...	...
	Total.	23	...	...	3	4	...	2	4	4	3	1	...	1	...	...	...	...	...	...	1	...	395
15	May 1	10	...	...	...	...	...	...	5	...	...	...	4	1	...	...	...	...	...	...	...	...	...
14	May 7	11	...	...	...	...	...	1	4	3	1	2	...	...	...	...	...	...	...	...	...	...	...
7	May 8	7	...	...	...	...	...	...	2	...	4	1	...	...	...	...	...	...	...	...	...	...	...
12	May 9	7	...	...	...	...	...	...	2	2	1	...	2	...	...	...	...	...	...	...	...	...	...
13	May 10	8	...	...	...	...	1	...	3	1	...	2	...	...	...	...	...	1	...	...	...	...	...
6	May 11	4	...	...	...	...	...	1	2	...	1	...	...	...	...	...	...	...	...	...	...	...	...
7	May 13	3	...	...	...	1	...	...	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...
14	May 14	7	...	...	...	1	...	2	2	1	1	...	...	...	...	...	...	...	...	...	...	...	...
16	May 15	6	...	...	...	...	3	...	...	...	1	...	2	...	...	...	...	...	...	...	...	...	...
16	May 16	10	...	...	...	1	3	...	1	2	...	...	3	...	...	...	...	...	...	...	...	...	...
14	May 17	9	1	...	...	2	...	1	...	...	2	1	...	2	...	...	...	...	...	...	...	...	...
12	May 18	6	...	...	...	...	1	...	...	1	2	...	...	1	...	...	...	...	...	...	...	...	...
11	May 19	6	...	...	...	...	...	...	2	2	...	...	...	1	1	...	...	...	...	...	...	...	...
20	May 20	6	...	...	...	...	...	1	2	...	1	...	...	...	...	...	1	...	...	...	1	...	...
11	May 21	6	...	...	...	...	...	1	...	2	1	...	...	...	1	...	...	...	...	...	...	1	...
8	May 22	3	...	...	...	...	...	...	1	1	1	...	...	...	...	...	...	...	...	...	...	...	...
5	May 23	2	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	1	...	...	...	...	...
4	May 24	2	...	...	...	...	...	...	1	...	...	1	...	...	...	...	...	...	...	...	...	...	...
7	May 25	1	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
5	May 26	2	...	...	...	...	...	1	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	Total.	116	1	...	...	5	8	9	29	16	17	7	11	5	2	...	1	2	...	...	1	1	2,112
10	June 2	4	...	...	1	...	1	...	1	...	...	...	...	...	1	...	...	...	...	...	...	...	...
6	June 8	3	...	...	1	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
13	June 17	9	...	...	...	2	4	...	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	Total.	16	...	...	2	4	5	...	4	...	...	...	...	...	1	...	...	...	...	...	...	...	248
Total for April, May, and June		155	1	...	5	13	13	11	37	20	20	8	11	6	3	...	1	2	...	...	2	1	2,755

Average time in fruit for April .... days.. 17.17
Average time in fruit for May .... do.... 18.21
Average time in fruit for June .... do.... 16.13
Average time in fruit for April, May, and June .... do.... 17.81

A total of 155 larvæ emerged, the time spent in the fruit varying from 11 to 30 days, with an average for the period of 17.81 days.

Table XXIX gives observations on 411 larvæ reaching maturity during May, June, and July, at Siloam Springs, Ark., in 1908. The fruit used was peach.

TABLE XXIX.—*Length of time spent in fruit by the plum curculio (egg and larval stages combined), Siloam Springs, Ark., 1908.*

Eggs deposited.	Date of egg deposition.	Mature larvæ developed.	Larvæ leaving fruit in specified days from deposition of eggs.																Total egg and larval days in fruit.
			15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
8	May 12	6						1		2	1	2							
6	May 13	6						1		1	3	1							
10	May 14	8					3	2	1	2									
38	May 15	35						21	10	3			1						
56	May 16	52					4	31	15	1			1						
39	May 17	37						10	20	4	1		2						
30	May 18	28								9	8	1	5	1	3	1			
10	May 19	6			3		1					2							
8	May 20	5		2	1				1		1								
16	May 21	16	1	3	3	1	1	5	1	1									
10	May 22	6					3		1			1		1					
16	May 23	13			1	2	1	4	2		2		1						
16	May 24	6								2	3	1							
7	May 25	6		2	2		2												
9	May 28	8			3		3		1				1						
9	May 29	8					5	2		1									
7	May 30	7						3				2	1	1					
8	May 31	7					1	1		1	2	1		1					
	Total.	260	1	7	13	3	24	81	52	27	21	11	12	4	3	1	...	...	5,424
10	June 2	8							4	2		2							
11	June 3	10								1	4	4		1					
16	June 4	14				2	7	2	1	1		1							
17	June 5	14					1		4	2	3	3		1					
9	June 6	9					2	6		1									
10	June 7	9					3		4	1		1							
5	June 10	5						1	2	2									
5	June 11	4						1		2	1								
7	June 14	7						1		1		1		2	2				
11	June 15	10				1		1		2	2	2	2						
12	June 16	8							4	3		1							
8	June 17	7						2		1		2	1	1					
5	June 19	4											1	2				1	
7	June 20	6					1	1		1	2		1						
11	June 22	10							1	4	3		2						
10	June 25	6									1	2	1		2				
10	June 27	6							2	1			1		1		1		
	Total.	137	...	...	...	3	14	15	22	25	16	19	9	7	5	...	1	1	3,057
5	July 7	3								1	1	1							
3	July 13	2											1		1				
4	July 15	3										2	1						
4	July 17	2											1	1					
2	July 22	1							1										
2	July 24	2					1	1											
3	July 26	1									1								
	Total.	14	...	...	...	...	1	1	1	1	2	3	3	1	1	...	...	...	328
Total for May, June, and July		411	1	7	13	6	39	97	75	53	39	33	24	12	9	1	1	1	8,809

Average time in fruit for May ....days.. 20.86
Average time in fruit for June ....do.... 22.31
Average time in fruit for July ....do.... 23.43
Average time in fruit for May, June, and July ....do.... 21.43

A total of 411 larvæ was under observation, the time spent in the fruit varying from 15 to 30 days. The average of all individuals was 21.43 days.

Observations were also made at Douglas, Mich., during 1910 by Mr. Hammar, on the complete life-cycle period of 121 individuals. For purposes of comparison the egg and larval stages combined are shown in Table XXX. The fruit used was peach. The average time for all individuals for June and July was 20.8 days.

TABLE XXX.—*Length of time spent in fruit by the plum curculio (egg and larval stages combined), Douglas, Mich., 1910.*

Eggs deposited.	Date of egg deposition.	Larvæ leaving fruit in specified days from deposition of eggs.												Total egg and larval days in fruit.
		16	17	18	19	20	21	22	23	24	25	26	27	
6	June 24	....	....	....	....	1	1	1	....	3	....	....	....	....
10	June 29	3	....	2	3	2	....	....	....	....	....	....	....	....
4	June 30	....	....	1	2	1	....	....	....	....	....	....	....	....
Total........		3	....	3	5	4	1	1	....	3	....	....	....	392
38	July 1	....	....	....	1	22	....	5	8	2	....	....	....	....
20	July 2	1	....	....	3	....	6	7	3	....	....	....	....	....
19	July 3	....	....	....	....	4	8	7	....	....	....	....	....	....
16	July 4	....	....	....	....	6	10	....	....	....	....	....	....	....
6	July 6	....	....	....	6	....	....	....	....	....	....	....	....	....
1	July 20	....	....	....	....	....	....	....	....	....	....	....	1	....
1	July 21	....	....	....	....	....	....	....	....	....	....	1	....	....
Total........		1	....	....	10	32	24	19	11	2	....	1	1	2,122
Total for June and July		4	....	3	15	36	25	20	11	5	....	1	1	2,514

Average time in fruit for June..days.. 19.6
Average time in fruit for July..do.... 21
Average time in fruit for June and July...............................do.... 20.8

In Table XXXI are shown the results of observations on the length of time spent in the fruit by the curculio at Barnesville, Ga., during 1910. The fruit used was peach.

TABLE XXXI.—*Length of time spent in fruit by the plum curculio (egg and larval stages combined), Barnesville, Ga., 1910.*

Date of egg deposition.	Mature larvæ developed.	Larvæ leaving fruit in specified days from deposition of eggs.																															Total egg and larval days in fruit.
		12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	
Apr. 8	11																			3	2	1	1	2	1							1	
9	29																		9		8	5	2	3	1	1							
11	68																4	8	17	15	12	3	1	2		1	3	2					
12	4																			2	1						1						
Total	112																4	8	26	20	23	9	4	7	2	2	4	2				1	3,465
May 9	5										4	1																					
10	8									2	4	2																					
12	13								3	6		4																					
13	1										1																						
17	1						1																										
18	1							1																									
19	1				1																												
21	15					7	8																										
23	2						1	1																									
25	1					1																											
26	16			14	2																												
Total	64			14	3	8	10	2	3	8	9	7																					1,135
June 16	1			1																													
17	1			1																													
18	3			2	1																												
20	2			1										1																			
22	2			1		1																											
24	3			1	1		1																										
25	3			1	1		1																										
27	5	1	1			1	1	1																									
28	3	1		2																													
29	5			4		1																											
30	3			1	2																												
Total	31	2	1	15	5	3	3	1						1																			463
July 1	1						1																										
3	3		1		2																												
4	4		2	2																													
5	14		4	2	1	5			2																								
6	11	2	5		1				1		1								1														
7	25	4	7	4	2	4	2	1			1																						
8	8		6	1	1																												
9	11	1	1	2	2	1			1			1	1							1													
12	7			5	1								1																				
14	7							1			2		1	1	1		1																
15	7						2	1	1	2	1																						
20	3				1		1							1																			
21	4				1	1	1			1																							
26	48			2	6	5	6	12	7	1	2	2		1	1	1	1	1															
30	45		6	13	1	9	3	3	1	1	3	3	1	1																			
Total	198	7	32	31	19	25	16	18	13	5	10	6	4	4	2	1	2	1	1	1													3,309
Aug. 7	15				1	4	2	3	1	1	1			1	1																		
9	43			1	3	3	6	2	3	1	2	5	6	4	3	2	2																
10	31						1	2			5	10	2	2	3	2	3	1															
17	2							1	1																								
Total	91			1	4	7	9	8	5	2	8	15	8	7	7	4	5	1															1,910
Total for season	496	9	33	61	31	43	38	29	21	15	27	28	12	12	9	5	11	10	27	21	23	9	4	7	2	2	4	2				1	10,282

Average time in fruit for April	days.. 30.94
Average time in fruit for May	do.... 17.74
Average time in fruit for June	do.... 14.94
Average time in fruit for July	do.... 16.76
Average time in fruit for August	do.... 20.99
Average for the season	do.... 20.73

The Barnesville records include observations on 496 larvæ, the period in fruit varying from 12 to 42 days. The average for the season was 20.73 days.

In Table XXXII are brought together from the preceding tables the totals showing the time spent in the fruit at the several localities. The horizontal bars mark weekly periods from time of deposition of eggs, beginning with the second week. The percentage of the total number of larvæ emerging weekly is also shown. From the Illinois, District of Columbia, and Georgia records it will be noted that there was a considerable emergence of larvæ in the localities in question during the second week. This was highest in the District of Columbia, where almost 30 per cent of the total larvæ emerged during the second week. In Georgia, 18.7 per cent of the larvæ came out during the second week in 1906, and during 1910 the proportion was 20.77 per cent. In all localities a notable majority of the larvæ emerged during the third week, and with the exception of the Georgia material during 1910, emergence from the fruit was practically over by the close of the fourth week from deposition of eggs.

TABLE XXXII.—*Length of time spent in fruit by the plum curculio (egg and larval stages combined), all localities.*

Days.	Griggsville, Ill., 1904.		Washington, D. C., 1905.		Youngstown, N.Y., 1905, and North East, Pa., 1906.		Myrtle, Ga., 1906.	
	Larvæ emerging.	Percentage of larvæ emerging by weeks.	Larvæ emerging.	Percentage of larvæ emerging by weeks.	Larvæ emerging.	Percentage of larvæ emerging by weeks.	Larvæ emerging.	Percentage of larvæ emerging by weeks.
10	....		2				....	
11	....		2				1	
12	2	1.70	9	29.79	....	....	1	18.70
13	2		17				13	
14	17		43				14	
15	42		58		....		6	
16	73		53		....		22	
17	137		14		....		36	
18	210	76.66	15	68.98	21	79.41	16	72.95
19	219		21		....		14	
20	179		8		....		8	
21	89		....		6		11	
22	77		....		....		5	
23	45		3		....		2	
24	38		....		7		1	
25	27	19.38	....	1.23	....	20.59	....	6.45
26	22		....		....		2	
27	23		....		....		....	
28	8		....		....		....	
29	7						2	
30	9						1	
31	3						....	
32	1	1.94	....	....	....	....	....	1.90
33	1						....	
34	1						....	
35	2						....	
36	1							
37	....							
38	....							
39	1	.32	....	....	....	....	....	....
40	....							
41	1							
42	1							
Total	1,238	100.00	245	100.00	34	100.00	155	100.00

TABLE XXXII.—*Length of time spent in fruit by the plum curculio (egg and larval stages combined), all localities*—Continued.

Days.	Siloam Springs, Ark., 1908.		Douglas, Mich., 1910.		Barnesville, Ga., 1910.	
	Larvæ emerging.	Percentage of larvæ emerging by weeks.	Larvæ emerging.	Percentage of larvæ emerging by weeks.	Larvæ emerging.	Percentage of larvæ emerging by weeks.
10						
11						
12					9	20.77
13					33	
14					61	
15	1				31	
16	7		4		43	
17	13				38	
18	6	57.91	3	68.60	29	41.13
19	39		15		21	
20	97		36		15	
21	75		25		27	
22	53		20		28	
23	39		11		12	
24	33		5		12	
25	24	41.60		31.40	9	17.54
26	12		1		5	
27	9		1		11	
28	1				10	
29	1				27	
30	1				21	
31					23	
32		.49			9	18.75
33					4	
34					7	
35					2	
36					2	
37					4	
38					2	
39						1.81
40						
41						
42					1	
Total	411	100.00	121	100.00	496	100.00

THE PUPA.

LENGTH OF TIME SPENT IN SOIL.

Considerable information has been obtained on the length of time spent by the curculio after entering the soil for pupation until the emergence of the beetle. As in the case of the statistics showing the length of time occupied in the egg and larval stages in the fruit, the present data have been obtained, often from miscellaneous collections of infested fruit, and at irregular intervals. Records are also given from collections where the complementary data were not obtained, or during another season.

Table XXXIII gives data on time spent in the ground by the curculio at Youngstown, N. Y., during 1906. A total of 826 larvæ were under observation, and the average time in soil for all beetles emerging was 31.04 days, varying from 19 to 54 days.

TABLE XXXIII.—*Length of time spent in soil by the plum curculio, Youngstown, N. Y., 1905.*

Date larvæ entered soil.	Larvæ.	Adults emerging in specified days from time of entering soil by larvæ.															
		19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
June 27	40	....	....	....	....	....	....	....	....	1	2	1	2	3	5	1	9
28	55	....	....	....	....	....	2	....	2	....	2	....	5	5	1	2	1
29	250	2	....	....	....	....	....	1	5	9	13	9	5	11	19	11	3
Total	315	2	....	....	....	....	2	1	7	10	17	10	12	19	25	14	13
July 1	150	....	....	....	....	....	....	3	....	7	9	10	11	16	....	7	7
2	126	....	....	....	....	....	....	1	....	3	....	4	2	3	8	6	4
3	135	....	....	....	....	....	....	....	....	....	13	3	6	2	3	8	2
7	70	....	....	....	2	....	2	2	....	5	5	2	3	3	....	....	....
Total	481	....	....	....	2	....	2	6	....	15	27	19	22	24	11	21	13
Total for season	826	2	....	....	2	....	4	7	7	25	44	29	34	43	36	35	26

Date larvæ entered soil.	Adults emerging in specified days from time of entering soil by larvæ.																Total adults	Total days spent in soil.
	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	54		
June 27	3	3	....	....	1	....	1	....	....	....	....	1	....	....	1	....	34	....
28	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	21	....
29	1	....	4	1	....	1	1	....	....	....	....	....	....	....	....	....	96	....
Total	4	3	4	1	2	1	2	....	....	....	....	1	....	....	1	....	151	4,711
July 1	....	....	....	2	....	5	....	....	....	....	....	....	....	....	....	1	78	....
2	....	2	1	1	....	2	....	1	....	....	....	....	....	....	....	....	38	....
3	....	....	....	....	1	....	1	....	....	....	....	....	....	....	....	....	39	....
7	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	25	....
Total	....	2	1	3	1	7	2	1	....	....	....	....	....	....	....	1	180	5,565
Total for season	4	5	5	4	3	8	4	1	....	....	....	1	....	....	1	1	331	10,276

Average time spent in the ground during June..........days.. 31.20
Average time spent in the ground during July..........do.... 30.92
Average time spent in the ground during season..........do.... 31.04

Table XXXIV shows similarly the time spent in the soil by curculios from miscellaneous collections at Myrtle, Ga., in 1906. A total of 459 larvæ entered the soil, yielding 376 adults. The average time in the soil of all beetles was 25.95 days, the range being from 16 to 46 days.

TABLE XXXIV.—*Length of time spent in the soil by the plum curculio, Myrtle, Ga., 1906.*

Date larvæ entered soil.	Larvæ.	Adults emerging in specified days from time of entering soil by larvæ.													
		16	17	18	19	20	21	22	23	24	25	26	27	28	29
May 17	63								1			8	5	10	8
19	30							1							
20	36													2	12
25	40							3	1	18	1				
27	71						2	5	13	12	13	6	3	8	
31	4									4					
Total	244						2	9	15	34	14	14	8	20	20
June 9	43										4	14	14	6	2
16	32	2	3			8	7			9		2			
Total	75	2	3			8	7			9	4	16	14	6	2
Total for May and June	319	2	3			8	9	9	15	43	18	30	22	26	22
Miscellaneous laboratory records from May 1 to July 7	140	1	1	3	6	4	4	11	19	19	17	16	7	8	2
Total for season	459	3	4	3	6	12	13	20	34	62	35	46	29	34	24

Date larvæ entered soil.	Adults emerging in specified days from time of entering soil by larvæ.														Total adults.	Total days spent in soil.
	30	31	32	33	34	35	36	37	38	39	40	42	45	46		
May 17	2	4	2		1										41	
19					1										2	
20	4	5	4												27	
25															23	
27				2	1				2						67	
31										1					5	
Total	6	9	6	2	3				2	1					165	4,405
June 9															40	
16															31	
Total															71	1,726
Total for May and June	6	9	6	2	3				2	1					236	6,131
Miscellaneous laboratory records from May 1 to July 7	1	1	2	3	2	2	1	1		4	1	1	2	1	140	3,621
Total for season	7	10	8	5	5	2	1	1	2	5	1	1	2	1	376	9,752

Average time spent in the ground during May..........days.. 26.67
Average time spent in the ground during June..........do.... 24.30
Average time spent in the ground during May and June..........do.... 25.98
Average time spent in the ground for season..........do.... 25.95

A few records were obtained by Mr. Girault at New Richmond, Ohio, during 1907. The 75 beetles emerging requiring an average of 22.21 days. Data for the month of June only were obtained, and the variation in time occupied by individuals is comparatively small, from 18 to 26 days. (See Table XXXV.)

TABLE XXXV.—*Length of time spent in the soil by the plum curculio, New Richmond, Ohio, 1907.*

Date larvæ entered soil.	Larvæ.	Adults emerging in specified days from time of entering soil by larvæ.									Total adults.	Total days spent in soil.
		18	19	20	21	22	23	24	25	26		
June 12	30	....	1	....	1	2	9	8	4	4	29	....
15	20	....	....	3	5	3	2	2	1	1	17	....
17	20	....	....	2	4	3	2	....	....	....	11	....
18	23	2	4	2	6	3	1	....	....	....	18	....
Total	93	2	5	7	16	11	14	10	5	5	75	1,666

Average time spent in the soil .... days.. 22.21

The records from Siloam Springs, Ark., are fairly extensive and cover the three months, May, June, and July. (See Table XXXV.) A total of 5,860 larvæ was used, yielding 1,774 adults. The range for the various beetles is from 19 to 47 days, with an average for all of 29 days. In this and other tables on the length of time spent in the ground, and also on the time spent in the fruit, the monthly totals and averages shown are largely arbitrary, in that the month is based upon the time of larvæ emerging from the fruit. Larvæ leaving the fruit in late May, for instance, would be in the ground during much of June.

TABLE XXXVI.—*Length of time spent in the soil by the plum curculio, Siloam Springs, Ark., 1908.*

Date larvæ entered soil.	Larvæ.	Adults emerging in specified days from time of entering soil by larvæ.														
		19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
May 14	328	....	....	....	....	....	....	....	....	....	1	3	....	1	5	4
18	574	....	....	....	....	....	....	2	1	3	12	11	10	13	23	14
21	965	....	....	....	....	....	....	....	....	4	8	11	17	14	2	16
24	550	....	....	....	....	....	....	1	3	10	12	2	37	17	21	2
27	629	....	....	....	....	2	1	5	....	47	54	62	14	2	32	16
30	719	....	....	....	....	....	....	21	31	23	11	54	30	9	....	7
Total	3,765	....	....	....	....	2	1	29	35	87	98	143	108	56	83	59
June 2	532	....	....	....	....	8	23	9	86	38	23	21	36	25	4	1
5	449	....	....	1	....	2	10	9	14	29	38	12	2	....	2	....
8	270	....	....	....	....	....	2	18	10	6	2	23	....	....	2	1
11	124	....	....	....	1	....	1	....	9	1	1	....	....	13	1	2
14	107	....	....	1	....	5	1	....	5	6	25	1	5	....	....	....
17	81	....	....	....	....	2	....	12	9	3	2	1	4	14	2	1
20	61	....	....	....	....	....	2	6	3	19	3	....	1	....	....	....
23	42	....	....	....	....	....	....	7	6	6	6	1	....	3	....	....
26	39	....	....	....	1	....	1	3	1	2	4	4	....	1	....	....
Total	1,705	....	....	2	2	17	40	64	143	110	104	63	48	56	11	5
July 22	146	....	....	6	33	8	4	3	14	7	4	1	3	2	1	1
25	119	1	1	1	3	17	12	5	6	3	6	2	1	....	1	....
28	74	....	....	3	3	7	3	3	1	....	....	2	....	2	1	....
31	51	....	....	....	....	1	2	....	....	....	1	....	....	....	....	....
Total	390	1	1	10	39	33	21	11	21	10	11	5	4	4	3	1
Total for season	5,860	1	1	12	41	52	62	104	199	207	213	211	160	116	97	65

TABLE XXXVI.—*Length of time spent in the soil by the plum curculio, Siloam Springs, Ark., 1908*—Continued.

Date larvæ entered soil.	Adults emerging in specified days from time of entering soil by larvæ.														Total adults.	Total days spent in soil.
	34	35	36	37	38	39	40	41	42	43	44	45	46	47		
May 14	2	14	6	2	2	2	3	1	1	....	....	....	1	2	50	....
18	12	1	6	11	2	1	....	....	....	....	1	1	....	....	124	....
21	29	17	1	....	4	4	....	....	....	....	1	....	1	2	131	....
24	6	3	1	1	....	2	5	....	....	....	....	....	....	....	123	....
27	3	....	7	4	1	....	....	1	....	1	1	....	....	....	253	....
30	14	2	1	....	5	1	....	1	1	....	....	....	....	....	211	....
Total	66	37	22	18	14	10	8	3	2	1	3	1	2	4	892	27,470
June 2	....	10	....	....	1	4	1	1	1	1	....	....	....	....	293	....
5	4	....	1	....	....	....	....	....	....	....	....	....	....	....	124	....
8	1	1	1	2	2	....	....	....	....	....	....	....	....	....	71	....
11	2	....	....	....	....	....	....	....	....	....	....	....	....	....	31	....
14	....	....	....	....	....	....	....	....	....	....	....	....	....	....	49	....
17	....	....	....	....	....	....	....	....	....	....	....	....	....	....	50	....
20	....	....	....	....	....	....	....	....	....	....	....	....	....	....	34	....
23	....	....	....	....	....	....	....	....	....	....	....	....	....	....	29	....
26	....	1	....	1	....	....	....	....	....	....	....	....	....	....	19	....
Total	7	12	2	3	3	4	1	1	1	1	....	....	....	....	700	19,434
July 22	....	....	....	....	1	....	1	....	....	....	....	....	....	....	89	....
25	1	....	....	1	....	1	....	....	....	....	....	....	....	....	62	....
28	....	1	....	1	....	....	....	....	....	....	....	....	....	....	27	....
31	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4	....
Total	1	1	....	2	1	1	1	....	....	....	....	....	....	....	182	4.547
Total for season	74	50	24	23	18	15	10	4	3	2	3	1	2	4	1,774	51,451

Average time spent in the ground during May..........days.. 30.79
Average time spent in the ground during June..........do.... 27.76
Average time spent in the ground during July..........do.... 24.93
Average time spent in the ground for season..........do.... 29.00

Data on time spent in ground in Washington, D. C., were obtained by Mr. Jones during 1908. A total of 1,114 adults was reared from 5,956 larvæ entering the soil, the range for individuals being from 18 to 56 days, with an average of 31.09 days for the season. (See Table XXXVII.)

TABLE XXXVII.—*Length of time spent in the soil by the plum curculio, Washington, D. C., 1908.*

Dates larvæ entered soil.	Larvæ.	Adults emerging in specified days from time of entering soil by larvæ.																		
		18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
May 27	187	....	....	....	....	....	....	....	....	....	....	....	....	2	1	5	8	3	7	11
28	283	....	....	....	....	....	....	....	....	....	....	3	4	2	12	4	5	27	13	7
30	218	....	....	....	....	....	....	....	....	....	....	....	3	2	4	17	1	1	4	5
31	297	....	....	....	....	....	....	....	....	....	....	....	....	2	6	6	7	1	....	1
Total	985	....	....	....	....	....	....	....	....	....	....	3	7	8	23	32	21	32	24	24
June 1	281	....	....	....	....	....	....	....	....	....	1	....	....	7	4	15	18	8	1	....
2	206	....	....	....	....	....	....	....	....	....	....	....	4	5	8	4	9	2	3	....
3	162	....	....	....	....	....	....	....	....	....	....	....	1	3	....	1	....	....	....	1
4	90	....	....	....	....	....	....	....	....	....	1	....	5	1	7	....	....	1	5	3
5	174	....	....	....	....	....	....	....	....	....	....	....	....	4	2	1	1	3	1	....
6	243	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....
7	208	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....
8	223	....	....	....	....	....	....	....	....	....	1	....	....	2	1	....	....	....	....	....
9	157	....	....	....	....	....	....	....	1	....	1	....	3	3	7	5	....	4	....	2
10	154	1	....	1	....	....	....	....	....	....	1	....	4	2	1	....	1	2	3	....
11	249	....	....	....	....	....	....	....	....	....	1	1	3	2	1	3	....	2	....	....

Table XXXVII.—*Length of time spent in the soil by the plum curculio, Washington, D. C., 1908*—Continued.

Dates larvæ entered soil.	Larvæ.	Adults emerging in specified days from time of entering soil by larvæ.																		
		18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
June 12	369	...	...	...	...	...	...	...	...	4	8	4	11	10	7	3	13	4	4	...
13	172	...	...	...	...	...	...	...	2	9	12	1	10	2	8	...	3	...	...	...
14	190	...	...	...	...	...	...	1	...	...	3	...	8	2	12	...	8	3	...	...
15	140	...	...	...	...	...	...	...	...	...	...	...	1	3	...	...	...	1	...	...
16	296	...	...	...	...	...	...	...	...	...	...	2	6	9	14	9	4	...	1	3
17	107	...	...	...	...	...	...	...	...	...	2	2	4	2	...	...	2	...	6	...
18	60	...	...	1	...	2	...	...	...	...	6	4	2	...	...	...	...	4	...	1
19	122	...	...	...	1	...	...	3	...	12	2	9	6	1	...	...	1	...	3	...
20	106	...	...	...	...	...	2	...	9	4	10	1	1	1	2	...	1	...	...	...
21	139	...	...	...	...	...	...	...	2	4	1	...	1	5	2	2	1	...	...	...
22	175	...	...	...	...	...	...	...	6	9	2	5	3	3	1	...	...	...	...	...
24	177	...	...	...	...	...	...	1	...	1	5	2	1	1	...	...	...	...	...	...
25	64	...	...	...	...	...	...	1	1	...	4	1	1	...	...	...	2	1	2	...
26	148	...	...	...	...	...	...	...	...	3	...	...	1	...	...	1	...	...	...	...
27	97	...	...	...	...	...	...	...	2	2	...	4	...	2	3	1	...	...	...	...
28	61	...	...	...	...	...	...	3	3	9	6	...	7	2	...	...	1	...	...	...
29	24	...	...	...	...	...	2	...	5	6	...	1	...	...	...	...	...	...	...	...
30	51	...	...	...	...	...	...	6	...	...	13	1	...	...	...	1	...	...	...	...
Total	4,645	1	...	2	1	2	4	15	31	63	80	38	83	72	81	46	65	36	29	10
July 1	47	...	...	...	...	...	...	...	...	2	3	2	1	...	...	...	...	...	...	...
2	42	...	...	...	...	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...
3	34	...	...	...	...	...	...	2	5	4	...	...	2	...	1	...	...	...	...	...
4	24	...	...	...	...	...	1	3	1	1	3	...	...	...	...	...	...	...	...	...
5	27	...	...	...	...	...	1	...	1	3	...	...	2	...	...	...	...	...	...	...
6	16	...	...	...	...	...	...	1	...	2	...	...	...	2	...	...	1	...	...	...
7	34	...	...	...	1	1	...	1	5	...	6	4	1	...	...	...	...	1	...	...
8	28	...	...	...	...	...	1	1	...	1	...	1	2	1	1	...	...	...	...	...
9	39	...	...	2	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...
10	10	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
11	[1] 11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
13	6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
14	[1] 8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Total	326	...	...	2	1	1	4	8	14	13	12	7	8	3	2	...	1	1	...	...
Total for season	5,956	1	0	4	2	3	8	23	45	76	92	48	98	83	106	78	87	69	53	34

Dates larvæ entered soil.	Adults emerging in specified days from time of entering soil by larvæ.																			Total adults. in soil.	Total days spent in soil.
	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	56		
May 27	3	11	15	3	3	1	3	1	2	...	...	...	2	...	1	1	...	...	2	85	....
28	12	14	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	103	....
30	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	38	....
31	...	1	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	25	....
Total	15	26	16	3	3	1	3	1	2	1	...	...	2	...	1	1	...	...	2	251	8,823
June 1	1	...	5	2	...	...	...	8	...	...	1	...	...	...	...	...	...	...	...	71	....
2	...	...	...	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	37	....
3	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	7	....
4	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	24	....
5	...	...	...	1	...	2	...	...	...	...	...	1	...	...	...	3	...	1	...	20	....
6	...	...	...	...	...	...	...	...	1	1	1	...	...	...	...	...	...	...	...	4	....
7	...	1	...	...	...	...	...	1	1	...	1	...	...	2	...	...	...	...	...	7	....
8	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5	....
9	2	4	...	...	...	2	...	...	1	...	...	2	...	...	...	...	...	...	...	37	....
10	...	...	...	...	...	1	1	...	...	...	...	...	...	...	...	...	...	...	...	18	....
11	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	14	....
12	...	1	3	7	4	...	...	...	...	1	...	...	...	...	...	...	...	...	...	84	....
13	...	9	17	8	1	1	...	1	...	...	...	...	...	...	...	...	...	...	...	84	....
14	...	1	...	3	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	42	....
15	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	6	....
16	3	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	52	....
17	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	19	....
18	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	20	....
19	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	39	....
20	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	31	....
21	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	18	....
22	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	29	....

TABLE XXXVII.—*Length of time spent in the soil by the plum curculio, Washington, D. C., 1908*—Continued.

Dates larvæ entered soil.	Adults emerging in specified days from time of entering soil by larvæ.																			Total adults in soil.	Total days spent in soil.
	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	56		
June 24																				11	
25																				13	
26[1]																				5	
27																				14	
28																				31	
29																				14	
30																				21	
Total	10	18	26	21	5	6	3	19	3	4	3	3	...	2	...	3	...	1	...	777	24,354
July 1																				8	
2																				2	
3																				14	
4																				9	
5																				7	
6																				6	
7							2													22	
8				2		1														11	
9																				3	
10		1				1														2	
13	1		1																	2	
Total	1	1	1	2	...	2	2	...	...	...	...	...	...	...	...	...	...	...	...	86	2,390
Total for season	26	45	43	26	8	9	8	11	5	5	3	3	2	2	1	4	0	1	2	1,114	35,567

[1] No beetles emerged.

Average time spent in the soil during May ....days.. 35.15
Average time spent in the soil during June ....do.... 31.34
Average time spent in the soil during July ....do.... 27.78
Average time spent in the soil for season ....do.... 31.09

Data obtained by Mr. Hammar at Douglas, Mich., during 1910 are shown in Table XXXVIII. A decided lengthening of the period is evident, the range being from 27 to 58 days, with an average for all individuals of 36.32 days. A total of 177 adults was reared from 207 larvæ.

TABLE XXXVIII.—*Length of time spent in the soil by the plum curculio, Douglas, Mich., 1910.*

Date larvæ entered soil.	Larvæ.	Adults emerging in specified days from time of entering soil by larvæ.																									Total adults.	Total days spent in soil.
		27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	15	47	48	49	50	55	58		
June 24	6							3		1		2															6	
29	10									1					2		1	2			1	2	1				10	
30	11			2			1		1	1											1						6	
Total	27	..	..	2	..	..	1	3	1	3	..	2	..	..	2	..	1	2	..	..	2	2	1	..	..	..	22	849
July 1	37							2	1	12	2	3	2		5			7		1					1	1	37	
2	24					1			2	3	3	3	3	1			3										19	
3	19				1				4			3	4		3	2	2										19	
4	18						1	1		1		4	3			2	1										13	
6	9	1	1					1				3	2														8	
8	9					1		2	2	1		1	1														8	
13	42				3	3	2	6	10	9	5																38	
20	12					1	2	1	2	3																	9	
25	10	1	1	2																							4	
Total	180	2	2	2	4	6	5	13	21	29	10	17	15	1	8	4	6	7	..	1	..	..	..	..	1	1	155	5,585
Total for season	207	2	2	4	4	6	6	16	22	32	10	19	15	1	10	4	7	9	..	1	2	2	1	..	1	1	177	6,434

Average time spent in ground during June ....days.. 38.59
Average time spent in ground during July ....do.... 36.03
Average time spent in ground during season ....do.... 36.32

Table XXXIX gives details of time spent in the ground of 1,568 individuals at Barnesville, Ga., covering the period May, June, July, and a part of August. A total of 2,917 larvæ was used. The range of the different individuals is from 21 days to 62 days—the longest yet noted—the average being 34.44 days.

TABLE XXXIX.—*Length of time spent in the soil by the plum curculio, Barnesville, Ga., 1910.*

Date larvæ entered soil.	Larvæ.	Adults emerging in specified days from time of entering soil by larvæ.																				
		21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
May 3	77	...	...	...	...	...	...	...	...	...	...	...	...	...	6	5	5	3	4	3	2	...
5	457	...	...	...	...	...	...	...	...	...	...	...	3	7	9	18	16	51	39	13	12	4
8	566	...	...	...	...	...	...	...	...	...	1	3	5	10	40	64	52	37	30	10	11	2
10	240	...	...	...	...	...	...	...	...	...	...	3	5	10	22	21	13	14	11	1	1	3
11	209	...	...	...	...	...	...	...	...	...	...	...	3	15	18	29	9	12	10	1	5	2
12	272	...	...	...	...	...	...	1	...	...	1	6	11	27	31	21	35	13	12	3	3	2
13	159	...	...	...	...	...	...	...	...	2	6	9	19	15	20	22	8	2	2	5	1	...
15	192	...	...	...	...	...	...	1	4	8	14	15	22	25	17	10	9	11	1	...	2	...
18	142	...	...	...	1	...	1	2	2	3	9	8	10	14	13	10	11	8	5	1	...	3
21	190	1	1	1	...	2	2	2	1	7	15	9	11	11	9	4	5	...	13	4	...	5
25	66	...	...	1	1	1	1	6	9	9	9	3	1	...	3	1	...	...	...	...	...	...
28	33	...	...	1	1	2	8	2	4	2	...	...	1	...	...	...	...	...	...	...	...	...
31	28	...	...	1	...	3	4	1	2	1	...	1	...	...	...	...	...	...	...	...	...	...
Total	2,631	1	1	4	3	8	16	15	22	32	55	57	91	134	188	205	163	151	127	41	37	21
June 5	28	...	...	2	1	3	3	1	2	2	...	1	...	...	...	...	...	...	...	...	...	...
10	14	...	...	2	2	...	1	...	1	1	...	...	...	...	...	...	...	...	...	...	...	...
Total	42	...	...	4	3	3	4	1	3	3	...	1	...	...	...	...	...	...	...	...	...	...
July 4	4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
9	4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
13	3	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...
15	36	...	...	...	...	2	2	...	3	2	3	...	...	2	...	1	...	...	...	...	...	...
18	23	...	...	...	1	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
23	25	...	...	1	2	1	1	1	6	...	...	1	1	...	1	...	...	...	1	1	...	...
26	51	...	...	1	3	5	1	1	2	...	...	1	1	1	...	1	1	1	...	...	...	3
28	27	...	1	...	...	1	4	...	2	1	1	...	...	1	...	...	...	...	...	...	...	1
29	12	...	...	...	...	...	1	3	...	...	...	...	1	1	...	...	...	...	...	...	...	...
30	17	...	...	...	2	...	1	1	1	...	2	1	1	...	...	1	...	...	...	...	...	...
31	8	...	...	1	...	2	...	1	...	1	1	...	...	...	...	...	1	...	...	...	...	...
Total	210	...	1	3	8	13	10	7	14	5	7	3	4	5	1	3	2	1	1	1	...	4
Aug. 1	10	...	...	...	...	1	...	...	1	1	...	...	...	...	...	1	...	...	...	...	...	...
3	11	...	...	1	1	...	1	1	2	1	...	...	1	...	...	...	...	...	...	...	...	...
7	13	...	...	...	1	4	1	...	...	1	1	...	...	...	...	...	...	...	...	...	...	...
Total	34	...	...	1	2	5	2	1	3	3	1	...	1	...	...	1	...	...	...	...	...	...
Total for season	2,917	1	2	12	16	29	32	24	42	43	63	61	96	139	189	209	165	152	128	42	37	25

Date larvæ entered soil.	Adults emerging in specified days from time of entering soil by larvæ.																					Total adults.	Total days spent in soil.
	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62		
May 3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	28	...
5	7	...	...	1	...	...	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	182	...
8	2	4	...	1	1	...	...	3	...	...	...	...	...	...	...	...	...	...	...	...	...	276	...
10	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	105	...
11	...	1	...	...	...	...	1	...	1	...	...	...	1	...	1	...	...	...	...	...	...	109	...
12	1	1	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	1	...	170	...
13	1	...	...	...	...	1	1	...	...	...	1	...	1	...	...	...	...	...	1	...	...	117	...
15	...	...	...	...	4	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	1	145	...
18	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	101	...
21	1	2	...	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	108	...
25	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	45	...
28	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	21	...
31	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	13	...
Total	12	8	...	2	5	1	5	4	2	1	1	...	2	...	1	...	1	...	1	1	1	1,420	49,570

TABLE XXXIX.—*Length of time spent in the soil by the plum curculio, Barnesville, Ga., 1910*—Continued.

Date larva entered soil.	Adults emerging in specified days from time of entering soil by larvæ.																					Total adults.	Total days spent in soil.
	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62		
June 5																						15	
10																						7	
Total																						22	572
July 4																						0	
9																						0	
13																						1	
15																						15	
18																						3	
23	1												1		1							20	
26		1		1	1				1						1							27	
28							1								1							14	
29																						6	
30	1								1													12	
31									1													8	
Total	2	1	...	1	1	...	1	...	3	...	...	...	1	...	3	...	...	...	...	...	...	106	3,317
Aug. 1																						4	
3																						8	
7																						8	
Total	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	20	543
Total for season	14	9	...	3	6	1	6	4	5	1	1	...	3	...	4	...	1	...	1	1	1	1,568	54,002

Average time spent in the ground during May .... days.. 34.91
Average time spent in the ground during June .... do.... 26.00
Average time spent in the ground during July .... do.... 31.28
Average time spent in the ground during August .... do.... 27.15
Average time spent in the ground during season .... do.... 34.44

In Table XL the totals from the foregoing tables on length of time spent in the soil are given for more ready comparison. The horizontal bars divide the period into weeks, beginning with the third week. The percentages of total adults emerging each week are also shown. Except in the Ohio records, which are perhaps abnormal, and the Georgia record for 1906, comparatively few beetles were out within three weeks from the time of entering the soil by the larvæ. During the fourth and fifth weeks, however, the great majority of beetles appear and by the close of the sixth week emergence has practically ceased.

TABLE XL.—*Length of time spent in the soil by the plum curculio; totals for all localities.*

Days in soil.	Locality and date.							
	Youngstown, N. Y., 1905.		New Richmond, Ohio, 1907.		Douglas, Mich., 1910.		Washington, D. C., 1908.	
	Beetles emerging.	Percentage of beetles emerging, by weeks.	Beetles emerging.	Percentage of beetles emerging, by weeks.	Beetles emerging.	Percentage of beetles emerging, by weeks.	Beetles emerging.	Percentage of beetles emerging, by weeks.
16								
17								
18			2				1	
19	2	0.60	5	40.00				0.63
20			7				4	
21			16				2	
22	2		11				3	
23			14				8	
24	4		10				23	
25	7	26.89	5	60.00		2.26	45	26.48
26	7		5				76	
27	25				2		92	
28	44				2		48	
29	29				4		98	
30	34				4		83	
31	43				6		106	
32	36	62.54			6	50.85	78	51.53
33	35				16		87	
34	26				22		69	
35	4				32		53	
36	5				10		34	
37	5				19		26	
38	4				15		45	
39	3	9.07			1	37.29	43	17.14
40	8				10		26	
41	4				4		8	
42	1				7		9	
43					9		8	
44							11	
45					1		5	
46	1	.60				8.48	5	3.32
47					2		3	
48					2		3	
49	1				1		2	
50							2	
51							1	
52							4	
53		.30				.56		.90
54	1						1	
55					1			
56							2	
57								
58					1			
59								
60						.56		
61								
62								
Total	331	100.00	75	100.00	177	100.00	1,114	100.00

TABLE XI.—*Length of time spent in the soil by the plum curculio; totals for all localities*—Continued.

Days in soil.	Locality and date.					
	Siloam Springs, Ark., 1908.		Myrtle, Ga., 1906.		Barnesville, Ga., 1910.	
	Beetles emerging.	Percentage of beetles emerging, by weeks.	Beetles emerging.	Percentage of beetles emerging, by weeks.	Beetles emerging.	Percentage of beetles emerging, by weeks.
16			3			
17			4			
18			3			
19	1	0.79	6	10.62		0.06
20	1		12			
21	12		13		1	
22	41		20		2	
23	52		34		12	
24	62		62		16	
25	104	49.49	45	69.95	29	10.01
26	199		46		32	
27	207		29		24	
28	213		34		42	
29	211		24		43	
30	160		7		63	
31	116		10		61	
32	97	43.58	8	15.80	96	51.02
33	65		5		139	
34	74		5		189	
35	50		2		209	
36	24		1		165	
37	23		1		152	
38	18		2		128	
39	15	5.47	5	2.85	42	35.91
40	10		1		37	
41	4				25	
42	3		1		14	
43	2				9	
44	3					
45	1		2		3	
46	2	.67	1	.78	6	1.85
47	4				1	
48					6	
49					4	
50					5	
51					1	
52					1	
53						.89
54					3	
55						
56					4	
57						
58					1	
59						
60					1	.26
61					1	
62					1	
Total	1,774	100.00	386	100.00	1,568	100.00

LENGTH OF PUPAL STAGE, AND TIME SPENT IN SOIL BEFORE AND AFTER PUPATION.

The data on the length of time spent in the soil do not show the length of the pupal instar, since a few days are spent by the larva in its cell before transforming to the pupa, and after the pupa has transformed to the adult, or beetle, a variable time is spent before the insect makes its escape from the ground. This latter period will vary

much, depending upon the character of the weather, whether dry or rainy. During periods of drought beetles appear to remain in their cells much longer than if the earth be moist or wet, as from rains. In fact, in orchards it has often been observed that shortly after a good soaking rain beetles were soon in evidence in large numbers, whereas previously they had been quite scarce.

Some data have been collected on the exact time spent in these three conditions in the soil and are brought together in the following tables. Writers appear not to have investigated this point heretofore. The data from a practical standpoint are important, since during the pupal stage the insect would be likely to suffer most from cultivations.

TABLE XLI.—*Length of pupal instar of the plum curculio and days spent in soil as larva, pupa, and adult, Washington, D. C., 1908.*

Individual No.	Date larva left fruit.	Date of pupation.	Date of transformation to adult.	Date beetle left soil.	Days in larval stage before pupation.	Days in pupal stage.	Days as beetle in soil.	Total days in soil.
1	June 6	June 19	June 27	July 5	13	8	8	29
2	...do...	June 18	...do...	July 6	12	9	9	30
3	...do...	June 22	...do...	Died.	16	5	....	....
4	...do...	June 18	...do...	July 5	12	9	8	29
5	...do...	June 19	June 29	July 6	13	10	7	30
6	...do...	June 18	...do...	July 8	12	11	9	32
7	...do...	...do...	June 27	July 6	12	9	9	30
8	...do...	June 22	June 29	July 8	16	7	9	32
9	...do...	June 18	June 27	July 6	12	9	9	30
10	...do...	June 19	June 29	July 5	13	10	6	29
11	...do...	June 18	...do...	July 6	12	11	7	30
12	June 9	June 24	July 3	July 11	15	9	8	32
13	...do...	June 22	June 30	...do...	13	8	11	32
14	...do...	...do...	...do...	July 7	13	8	7	28
15	...do...	...do...	...do...	...do...	13	8	7	28
16	...do...	...do...	July 1	July 6	13	9	5	27
17	...do...	June 19	June 29	July 5	10	10	6	26
18	...do...	June 23	...do...	July 8	14	6	9	29
19	...do...	...do...	June 30	Died.	14	7	....	....
20	...do...	...do...	July 1	July 7	14	8	6	28
21	...do...	...do...	June 29	...do...	14	6	8	28
22	...do...	...do...	June 30	...do...	14	7	7	28
Total					290	184	155	587
Average for all individuals					13.18	8.36	7.75	29.35

From the table it will be noted that the average time spent in the soil before pupation for the 22 individuals is 13.18 days; the length of the pupal instar, 8.36 days; and the period occupied in the soil as a beetle before emergence, 7.75 days. The average time spent in the ground from entrance of larvæ to emergence of adult is 29.35 days.

These larvæ were kept in large glass vials, the soil being a sandy loam. Specimens were kept in an out-of-doors breeding cage in the insectary yard, at Washington, D. C., where the temperature would be somewhat higher than in the soil.

Mr. Hammar made observations during 1910, at Douglas, Mich., on a large series of individuals, as detailed in Table XLII.

TABLE XLII.—*Length of pupal instar of the plum curculio and time spent in the soil as larva and as adult, Douglas, Mich., 1910.*

Individual No.	Date larva left the fruit.	Date of pupation.	Date of transformation to beetle.	Date beetle left the soil.	Days in larval stage before pupation.	Days in pupal stage.	Days as beetle in soil.	Total days in soil.
1	June 30	July 11	July 26	Aug. 1	11	15	6	32
2	...do....	July 12	July 25	July 29	12	13	4	29
3	July 2	July 13	July 27	Aug. 2	11	14	6	31
4	...do....	July 21	Aug. 2	Aug. 7	19	12	5	36
5	July 4	...do....	...do....	Aug. 8	17	12	6	35
6	...do....	July 22	Aug. 1	Aug. 5	18	10	4	32
7	...do....	...do....	Aug. 2	Aug. 8	18	11	6	35
8	July 6	July 20	July 30	Aug. 3	14	10	4	28
9	...do....	July 21	...do....	...do....	15	9	4	28
10	July 8	July 17	Aug. 1	Aug. 10	9	15	9	33
11	...do....	July 19	Aug. 2	...do....	11	14	8	33
12	...do....	July 20	Aug. 3	Aug. 8	12	14	5	31
13	...do....	July 21	Aug. 1	Aug. 10	13	11	9	33
14	...do....	...do....	Aug. 3	Aug. 12	13	13	9	35
15	...do....	July 22	Aug. 2	Aug. 10	14	11	8	33
16	...do....	...do....	Aug. 3	Aug. 14	14	12	11	37
17	...do....	...do....	...do....	Aug. 16	14	12	13	39
18	July 13	July 23	Aug. 8	Aug. 13	10	16	5	31
19	...do....	July 24	Aug. 9	Aug. 15	11	16	6	33
20	...do....	...do....	Aug. 7	Aug. 16	11	14	9	34
21	...do....	...do....	Aug. 8	Aug. 17	11	15	9	35
22	...do....	...do....	...do....	Aug. 15	11	15	7	33
23	...do....	...do....	...do....	Aug. 16	11	15	8	34
24	...do....	...do....	Aug. 9	...do....	11	16	7	34
25	...do....	...do....	Aug. 7	...do....	11	14	9	34
26	...do....	...do....	...do....	...do....	11	14	9	34
27	...do....	...do....	...do....	...do....	11	14	9	34
28	...do....	...do....	Aug. 8	Aug. 15	11	15	7	33
29	...do....	...do....	...do....	Aug. 16	11	15	8	34
30	...do....	...do....	Aug. 9	Aug. 17	11	16	8	35
31	...do....	...do....	Aug. 8	...do....	11	15	9	35
32	...do....	...do....	...do....	...do....	11	15	9	35
33	...do....	...do....	Aug. 4	Aug. 15	11	11	11	33
34	...do....	...do....	Aug. 8	Aug. 16	11	15	8	34
35	...do....	July 25	...do....	Aug. 17	12	14	9	35
36	...do....	...do....	Aug. 9	Aug. 18	12	15	9	36
37	...do....	...do....	...do....	...do....	12	15	9	36
38	...do....	...do....	...do....	Aug. 17	12	15	8	35
39	...do....	...do....	...do....	...do....	12	15	8	35
40	...do....	...do....	...do....	Aug. 16	12	15	7	34
41	...do....	...do....	Aug. 8	Aug. 12	12	14	4	30
42	...do....	...do....	...do....	Aug. 13	12	14	5	31
43	...do....	...do....	...do....	Aug. 18	12	14	10	36
44	...do....	...do....	...do....	Aug. 14	12	14	6	32
45	...do....	...do....	Aug. 9	Aug. 16	12	15	7	34
46	...do....	...do....	...do....	Aug. 14	12	15	5	32
47	...do....	...do....	Aug. 10	Aug. 15	12	16	5	33
48	...do....	...do....	...do....	Aug. 18	12	16	8	36
49	...do....	...do....	Aug. 9	Aug. 12	12	15	3	30
50	...do....	...do....	...do....	Aug. 17	12	15	8	35
51	...do....	July 20	Aug. 8	Aug. 18	7	19	10	36
52	...do....	July 26	Aug. 9	Aug. 12	13	14	3	30
53	...do....	...do....	Aug. 10	Aug. 18	13	15	8	36
54	...do....	...do....	...do....	Aug. 13	13	15	3	31
55	...do....	Aug. 1	Aug. 16	Aug. 23	19	15	7	41
56	July 20	July 30	Aug. 15	Aug. 22	10	16	7	33
57	...do....	...do....	...do....	Aug. 23	10	16	8	34
58	...do....	...do....	Aug. 14	Aug. 22	10	15	8	33
59	...do....	...do....	Aug. 15	Aug. 23	10	16	8	34
60	...do....	...do....	...do....	Aug. 21	10	16	6	32
61	...do....	Aug. 1	...do....	Aug. 23	12	14	8	34
62	...do....	...do....	...do....	...do....	12	14	8	34
63	...do....	...do....	...do....	...do....	12	14	8	34
64	...do....	Aug. 2	Aug. 14	Aug. 20	13	12	6	31
65	July 25	Aug. 3	Aug. 17	Aug. 23	9	14	6	29
66	...do....	...do....	...do....	Aug. 22	9	14	5	28
67	...do....	Aug. 4	Aug. 18	Aug. 23	10	14	5	29
68	...do....	Aug. 7	...do....	...do....	13	11	5	29
Total					818	960	485	2,263
Average for all individuals					12.03	14.12	7.10	33.28

These individuals were also kept in vials under out-of-doors conditions. The average of the 68 examples for the time spent in soil previous to pupation is seen to be 12.03 days; for the pupal stage, 14.12 days; and an average of 7.10 days was spent in the soil before exit of adult, after transformation. The average of the total days in the soil for all stages is 33.28 days. The range in time in soil before pupation is from 7 to 19 days. The range for the pupal stage is from 9 to 19 days; and for the beetle in the earth, 3 to 13 days. The entire time spent in the ground varies from 28 to 39 days.

Similar data from Barnesville, Ga., obtained during 1910, are shown in Table XLIII. Records for 38 individuals were obtained from May 20 to July 11, when the last beetle left the soil. The insects were placed in glass-bottomed boxes containing a shallow layer of sand and kept in a dark box under shade out of doors.

TABLE XLIII.—*Length of pupal instar of the plum curculio and time spent in the soil as larva and as adult, Barnesville, Ga., 1910.*

Individual No.	Date larva left fruit.	Date of pupation.	Date of transformation to beetle.	Date beetle left the soil.	Days in larval stage previous to pupation.	Days in pupal stage.	Days as beetle in soil.	Total days in soil.
1	May 20	June 5	June 14	June 20	16	9	6	31
2	...do....	June 7	June 17	June 22	18	10	5	33
3	...do....	May 31	June 8	June 14	11	8	6	25
4	...do....	June 3	June 13	June 19	14	10	6	30
5	...do....	...do....	June 12	June 20	14	9	8	31
6	...do....	...do....	June 13	...do....	14	10	7	31
7	...do....	June 4	June 14	June 21	15	10	7	32
8	...do....	June 5	June 15	...do....	16	10	6	32
9	...do....	...do....	June 14	June 20	16	9	6	31
10	...do....	...do....	June 15	...do....	16	10	5	31
11	...do....	...do....	June 14	June 23	16	9	9	34
12	...do....	...do....	June 16	June 24	16	11	8	35
13	...do....	June 6	...do....	June 21	17	10	5	32
14	May 21	June 3	June 11	June 20	13	8	9	30
15	...do....	June 8	June 18	June 24	18	10	6	34
16	...do....	June 9	June 19	June 25	19	10	6	35
17	...do....	June 12	June 21	June 27	22	9	6	37
18	...do....	June 16	June 25	July 1	26	9	6	41
19	...do....	June 17	June 26	July 2	27	9	6	42
20	June 4	...do....	June 25	June 29	13	8	4	25
21	June 7	June 25	July 3	July 6	18	8	3	29
22	...do....	June 26	July 6	July 11	19	10	5	34
23	June 8	June 27	...do....	July 12	19	9	6	34
24	...do....	June 28	July 7	July 9	20	9	2	31
25	...do....	...do....	...do....	July 14	20	9	7	36
26	June 10	June 25	July 4	July 9	15	9	5	29
27	June 11	June 23	July 1	July 7	12	8	6	26
28	...do....	...do....	July 2	...do....	12	9	5	26
29	...do....	...do....	...do....	...do....	12	9	5	26
30	June 12	June 25	July 4	July 10	13	9	6	28
31	...do....	...do....	...do....	...do....	13	9	6	28
32	...do....	...do....	...do....	July 8	13	9	4	26
33	...do....	June 28	July 7	July 11	16	9	4	29
34	June 13	June 27	July 6	July 10	14	9	4	27
35	...do....	...do....	...do....	...do....	14	9	4	27
36	...do....	...do....	...do....	...do....	14	9	4	27
37	...do....	...do....	...do....	July 11	14	9	5	28
Total					595	340	208	1,143
Averages for all individuals					16.08	9.18	5.62	30.89

These figures show interesting differences from the Michigan records. Thus, the average number of days for all larvæ in soil before pupation is 16.08, as against 12.03 in the Michigan records. The average length of the pupal stage at Barnesville, 9.18 days, is notably less than shown for Michigan, namely, 14.12 days. However, adding together the average larval and pupal stages for each locality shows these sums to differ by only 1 day, the lengthening of the larval stage in the ground in Georgia being offset by a shorter period in the pupal condition. In the Georgia records the average time spent by the adults in the ground before emerging is 5.62 days. The average time of the 37 individuals spent in the soil is 30.89 days.

DEPTH OF PUPAL CELL.

Great diversity of opinion was expressed by the earlier writers as to the depth to which curculio larvæ entered the soil for pupation, and no very accurate observations on this point seem to have been made. Riley states that they go below the surface from 4 to 6 inches, and remarks that he never found them deeper than 6 inches. Riley and Howard, writing in 1888, state that the larvæ seldom burrow to a greater depth than 4 or 5 inches. Other writers say "a few inches," "2 to 3 inches," "a short distance," and one states "15 to 36 inches."

Prof. Crandall was perhaps the first to secure exact data on this point. In 1903 observations were made on the depth of pupæ in ground, including 78 individuals secured under natural conditions under trees in orchards, 79 from bottomless soil boxes, and 22 from breeding cages in the laboratory—a total of 179. In 1904 data were obtained on 645 individuals, 24 by digging earth under trees, 298 from soil boxes, and the remaining 323 from larvæ pupating in the laboratory. Using the records for both seasons obtained under out-of-doors conditions—that is, under trees or in soil boxes, sod and cultivated—we find that of the total 482, 336, or 69.70 per cent, pupated within 1 inch of the surface, and 475, or 98.54 per cent, within 2 inches of the top of the soil.

Prof. Crandall's laboratory records do not show important differences from those obtained out-of-doors. Some individuals pupated at a greater depth, as 8 at 3 inches, 1 at $3\frac{1}{4}$ inches, and 2 at $3\frac{1}{2}$ inches, as against 1 at $2\frac{1}{4}$ inches, 3 at $2\frac{1}{2}$ inches, and 3 at $2\frac{3}{4}$ inches, under out-of-doors conditions, due perhaps to a greater dryness of the soil in the laboratory.

Messrs. Girault and Rosenfeld, in Georgia, in 1906, obtained records on the depth of pupation of 121 larvæ under natural out-of-doors conditions, the soil being a sandy loam. One hundred, or 82.64 per cent, pupated within 1 inch of the surface, and all, or 100 per cent, within 2 inches. Other records on depth of pupation in the

same soil in the laboratory do not differ essentially, though 5 larvæ went to a depth of 2¼ inches, one to 2½ inches, and two to 3 inches. The above figures are better shown in Table XLIV, which includes also records on 40 larvæ at the insectary in Washington, obtained by use of a soil box, under natural conditions, the soil being a sandy garden loam.

TABLE XLIV.—*Showing depth to which larvæ of the plum curculio enter soil for pupation, various localities.*

Localities.	¼ inch.	½ inch.	¾ inch.	1 inch.	1¼ inches.	1½ inches.	1¾ inches.	2 inches.	2¼ inches.	2½ inches.	2¾ inches.	3 inches.	3¼ inches.	3½ inches.	Total.
Illinois:															
1903	.....	45	55	40	19	16	3	1	.....	.....	.....	.....	.....	.....	179
1904	48	137	100	91	50	77	39	51	14	15	12	8	1	2	645
Georgia: 1906	34	61	34	21	23	11	17	10	5	1	.....	2	.....	.....	219
District of Columbia: 1905	1	3	7	7	10	6	2	.....	1	1	.....	2	.....	.....	40
Total	83	246	196	159	102	110	61	62	20	17	12	12	1	2	1,083
Percentages	7.66	22.72	18.10	14.68	9.42	10.16	5.63	5.73	1.85	1.56	1.11	1.11	0.09	0.18	100

Of the total of 1,083 larvæ, 684, or 63.16 per cent, pupated within 1 inch of the surface, and 1,019, or 94.09 per cent, within 2 inches of the surface. These figures show that the great majority of larvæ pupate comparatively close to the surface of the soil—within a distance of 2 inches—a fact to be remembered as bearing on the possibility of destroying the pupæ by timely and proper cultivations, as will be later discussed (p. 176).

SOIL CONDITIONS AFFECTING TRANSFORMATIONS OF THE CURCULIO IN THE GROUND.

Probably no one natural factor, aside from abundance of food, exerts a greater influence upon the welfare of the curculio than the condition of the soil during its occupancy by the insect, especially the degree of moisture. It is a matter of common observation that the beetles may long be retarded in their appearance from the ground by drought and that after a soaking rain they will come out literally in swarms. The necessity for adequate soil moisture for their successful underground transformations and their emergence is doubtless the most important single influence which has prevented their spread into the arid regions to the west. As shown under the heading of geographic distribution, the species has not extended its range much west of the one hundredth meridian, which marks, in a general way, the beginning of the arid region.

Some experiments have been made at different times, but especially during 1910, to secure data on the influence, on the transformations of the insect, of different kinds of soil and of normally moist as compared with dry soil.

In Table XLV are shown results from three root cages. In the first the soil was kept normally moist; the second one was moist at the beginning of the experiment but was allowed to dry out; in the third cage the soil was dry at the start. June 4, 20 larvæ were added to cage I, 20 to cage II, and 12 to cage III.

TABLE XLV.—*Effect of moisture on transformations of the plum curculio in the ground, Barnesville, Ga., 1910.*

No. of larvæ.	Treatment.	Date larvæ entered soil.	Date of pupation.	Life of larvæ in soil.	Date of transformation.	Pupal stage.	Adult left soil.	Life as adult in soil.	Total life in soil.
				Days.		*Days.*		*Days.*	*Days.*
1	Soil kept normally moist.	June 4	June 14	10	June 23	9	July 3	10	29
2		do	do	10	June 22	8	do	11	29
3		do	do	10	June 23	9			
4		do	do	10	do	9	July 3	10	29
5		do	June 15	11	do	8	June 30	7	26
6		do	do	11	June 22	7			
7		do	do	11	June 23	8	June 29	6	25
8		do	June 16	12	June 24	8	July 1	7	27
9		do	June 18	14	June 26	8	do	5	27
10		do	do	14	do	8	July 4	8	30
11		do	June 19	15	June 27	8			
12		do	June 20	16	June 28	8	July 7	9	33
13		do	July 3	29	July 11	8			
13	Total			173		106		73	255
	Average			13.30		8.15		8.11	28.33
1	At start soil normally moist but allowed to dry out.	June 4	June 13	9	June 22	9			
2		do	do	9	do	9			
3		do	do	9	do	9	July 4	12	30
4		do	June 14	10	June 23	9			
5		do	do	10	June 22	8			
6		do	do	10	June 23	9			
7		do	do	10	do	9			
8		do	June 15	11	do	8			
9		do	do	11	June 24	9			
10		do	June 16	12	June 27	11			
10	Total			101		90		12	30
	Average			10.1		9.0		12	30
1	Soil entirely dry	June 4	June 14	10	June 23	9			
2		do	do	10	do	9			
2	Total			20		18			
	Average			10		9			

As will be seen, 13 larvæ in cage I entered the soil and reached the pupal stage; only 9 adults, however, emerged. In cage II, 10 larvæ passed the pupal stage, but only one adult succeeded in emerging. In the third cage most of the larvæ were unable to work themselves below the soil to any extent on account of dryness of earth, and by June 13 several were found dead, evidently drying up. Only two individuals reached the pupal stage, and no adults emerged.

A series of observations was started on larvæ placed in soil in jelly glasses, as detailed in Table XLVI.

TABLE XLVI.—*Effect of moisture on transformations of the plum curculio in the ground, Barnesville, Ga., 1910.*

SOIL KEPT NORMALLY MOIST.

Jar No.	Larvæ.	Beetles emerging.	Average time in soil.	Per cent emerging as adults.
			Days.	
I	16	15	25.53	93.7
II	13	12	25.50	92.3
V	11	11	25.27	100.0
VI	17	13	26.15	76.5
VIII	8	8	28.12	100.0
XI	15	12	25.91	80.0
XIII	12	11	24.00	91.7
XVII	14	14	23.35	100.0
Total	106	96		
Percentage				90.56

SOIL AT FIRST MOIST, BUT ALLOWED TO DRY OUT.

Jar No.	Larvæ.	Beetles emerging.	Average time in soil.	Per cent emerging as adults.
XII[1]	15	2	27.50	13.3
XIV	12	3	25.66	25.0
XV[2]	14	2	28.00	14.3
XVI	12	8	26.37	66.6
XVIII	5	3	26.66	60.0
Total	58	18		
Percentage				31.03

SOIL DRY.

Jar No.	Larvæ.	Beetles emerging.	Average time in soil.	Per cent emerging as adults.
III	13	None.		
IV	10	None.		
VII	17	None.		
IX	9	None.		
X	12	None.		
Total	61			
Percentage				

[1] Soil watered 34 days after entering of soil by larvæ, 9 more beetles promptly appearing.
[2] Soil watered 36 days after entering of soil by larvæ, one beetle appearing the following day.

In the series of jars with normally moist soil, a total of 106 larvæ was used, yielding 96 adults, or 90.56 per cent. In jars where the soil was allowed to dry out, and without further watering, a noticeable decrease in the number of adults emerging is shown. From a total of 58 larvæ only 18 adults, or 31.03 per cent, developed. Where dry soil was used no adults whatever developed from the 61 larvæ used.

Four wooden boxes, 10 by 12 by 8 inches, were used in a more extensive test. In two of the boxes ordinary Georgia red clay was used, one being kept moist, while the other was dry but was subsequently watered as stated in the footnote. In the other two boxes a sandy loam was used, one being kept moist and the other dry. The soil in all boxes, however, was moist at the time the larvæ were put in, to enable them better to establish themselves. The boxes were covered with wire screen and kept out of doors protected from the sun. (For detail, see Table XLVII.)

TABLE XLVII.—*Effect of moisture on transformations of the plum curculio in the ground, Barnesville, Ga., 1910.*

Dates of emergence of adults and parasites.	Red clay kept normally moist (247 larvæ, Aug. 6–9).		Red clay moist at start but allowed to dry out (245 larvæ, Aug. 6–9).		Sandy loam kept normally moist (280 larvæ, Aug. 10–13).		Sandy loam moist at start but allowed to dry out (288 larvæ, Aug. 10–13).	
	Adults.	Parasites.	Adults.	Parasites.	Adults.	Parasites.	Adults.	Parasites.
Aug. 29		2		1				
30		3						
31		6						
Sept. 1	1	4				1		1
2	2	4				5		3
3	2	5			2	4		2
4	19	3			2	3		3
5	15	1			8	7		1
6	17	1			16	7		3
7	17	1	[1] 67		28	2		
8	12		8	1	12		1	
9	15		1		18	1		
10	12		1		14		2	
11	6				5	1	2	
12	6				7			
13	7				13			
14	7				11		1	
15	6				4	1		
16					3			
17	5				3			
18	2		1		3			
19	5				1			
20	1				4			
21	1				2			
22					2			
23	1							
24					5			
25	2							
26								
27								
28								
29	1				1			
30	1							
Total	163	30	78	2	164	32	6	13
Percentage	65.99		31.84		58.57		2.08	
Percentage adults and parasites emerging	78.13		32.65		70.00		6.90	

[1] The soil in box had dried so hard that it was considered impossible for any beetles to emerge. To determine the effect of wetting, water was applied on the evening of Sept. 6. The record shows the prompt emergence of the beetles.

In the case of the red-clay soil kept normally moist, 65.99 per cent of the larvæ transformed to adults, or if account be taken of the parasites, 78.13 per cent. From the box containing dry red clay soil it is highly probable that not a single adult would have been able to escape without the thorough soaking given on September 6. That many beetles were still alive is shown by the prompt emergence of 67 the day following, and 11 more during the next 3 days. The effect of drought on this type of soil is also shown to reduce emergence of parasites. A total of 32.65 per cent of the individuals in this box are accounted for as beetles or parasites.

From the normally moist sandy-loam soil 164 beetles developed and 32 parasites, giving a total percentage of individuals accounted for of 70 per cent as compared with the emergence record of 6.90 per cent of the dry sandy loam soil.

From all of the foregoing data it is clearly shown how important is moisture for the transformation of the curculio in the soil. In general, no adults issued from a dry soil, and in a soil moist at time of entrance of larvæ, but allowed naturally to dry out, the number emerging was greatly reduced, from 88.23 per cent to 27.94 per cent, as compared with condition of checks. Dryness does not appear to affect the length of the stages, as the average days spent in the soil of individuals of both series is about the same. As shown in Table XLV the mortality seems to be largely after transformation to the beetle stage has occurred, if the soil was moist at the time the larvæ entered.

THE ADULT.

PERIOD OF EMERGENCE OF BEETLES.

As elsewhere shown (p. 48) oviposition extends over several weeks, or even months. It follows that the beetles resulting from the eggs will emerge during a similar interval of time, and this period may be considerably modified by the condition of the soil, as whether dry, or sufficiently moist to permit the prompt escape of the beetle when sufficiently hardened.

Records of the emergence of beetles during the season, as obtained from the larval emergence records detailed in Table XXII, are shown in Table XLVIII from Barnesville, Ga.; Siloam Springs, Ark.; Washington, D. C.; and Douglas, Mich.

TABLE XLVIII.—*Emergence from the soil of beetles of the plum curculio during the season, several localities.*

Dates of emergence.	Barnesville, Ga.	Siloam Springs, Ark.	Washington, D. C.	Douglas, Mich.	Dates of emergence.	Barnesville, Ga.	Siloam Springs, Ark.	Washington, D. C.	Douglas, Mich.
June 6	9	...	...	...	July 1	9	14	69	...
7	13	...	...	...	2	2	83	41	...
8	18	...	...	...	3	6	107	49	...
9	26	...	...	...	4	6	30	54	...
10	33	...	...	...	5	...	12	60	...
11	105	1	...	...	6	4	3	15	...
12	135	5	...	...	7	...	55	8	...
13	132	1	...	...	8	3	2	20	...
14	150	4	...	...	9	1	2	39	...
15	141	17	...	...	10	...	9	43	...
16	108	15	...	...	11	...	7	29	...
17	128	16	...	...	12	3	56	17	...
18	61	36	...	...	13	...	12	39	...
19	47	45	...	...	14	...	14	15	...
20	57	44	...	...	15	...	2	96	...
21	50	45	...	...	16	1	16	31	...
22	38	7	...	...	17	...	7	80	...
23	43	115	...	...	18	...	64	56	...
24	33	133	...	...	19	...	10	16	...
25	19	142	3	...	20	...	13	34	...
26	16	65	6	...	21	...	10	141	...
27	1	28	3	...	22	...	3	197	...
28	24	181	22	...	23	...	5	67	...
29	9	100	14	...	24	...	9	55	...
30	11	45	14	...	25	...	6	25	...
					26	...	...	...	...
Total.	1,407	1,045	62	...	27	...	4	44	...
					28	...	1	32	...

TABLE XLVIII.—*Emergence from the soil of beetles of the plum curculio during the season, several localities*—Continued.

Dates of emergence.	Barnesville, Ga.	Siloam Springs, Ark.	Washington, D.C.	Douglas, Mich.	Dates of emergence.	Barnesville, Ga.	Siloam Springs, Ark.	Washington, D.C.	Douglas, Mich.
July 29		1	15		Sept. 1	16	2		
30		2	7		2	3	1		
31			7		3	5	2		
Total.	35	559	1,401		4	3			
Aug. 1			12	2	5	16			
2		1		2	6	3			
3		4	10	3	7	5			
4			4	6	8				
5		1	4	3	9	2			
6			2	11	10	5			
7			1	6	11				
8		2	2	5	12				
9	2			6	13				
10	2	1	1	6	14	8			
11	2		1	6	15	3			
12	5	6		3	16				
13	2	35		10	17	3			
14	3	10		6	18	2			
15	1	5		4	19	3			
16	2	6		6	20	3			
17	3	31	3	3	21				
18	4	22		4	22				
19	6	12	4	2	23				
20	11	14		1	24				
21	3	9	3	4	25				
22	5	13		2	26				
23	29	6		1	27				
24	5	5			28	2			
25	21				Total.	82	5		
26	16	3			Total for season.	1,718	1,803	1,510	102
27	13								
28	3	4							
29	13								
30	24								
31	19	4							
Total.	194	194	47	102					

The data do not show the entire range of time over which beetles may emerge from a given locality, but they indicate about what happens in a particular orchard. Later records could doubtless have been gotten had other fruits been used as a source of larvæ, after the gathering of the peach crop.

The Barnesville, Ga., record is perhaps the most nearly complete, since at that place there is little fruit available for the curculio after the harvesting of Elberta peaches. This record shows an interval from June 6 to September 28 during which beetles were emerging—a period of 114 days (see fig. 21). But from larvæ from some late seedling peaches beetles continue to emerge up to November 9, giving a total period of 156 days. Only the cold weather prevented still further emergence, since on November 10 there still remained in the soil fully matured adults as well as many pupæ and even a few larvæ. These were from a batch of 107 larvæ from seedling peaches, the last to be secured. The larvæ left the fruit September 18 to October 15, and 15 beetles emerged October 19 to November 9. The soil in the box was examined November 10, when there were found 6 beetles ready to emerge, 28 live healthy pupæ, 5 live

larvæ, and 1 cocoon of *Triaspis curculionis*, var. *rufus*. It thus appears possible that some few individuals may pass the winter in the soil, both in the adult stage and as pupæ, and emerge the following spring.

During 1905–6, at Fort Valley, Ga., adults were reared as early as May 22 and as late as October 5, an interval of 136 days. In this case the food for the late rearings was Cratægus.

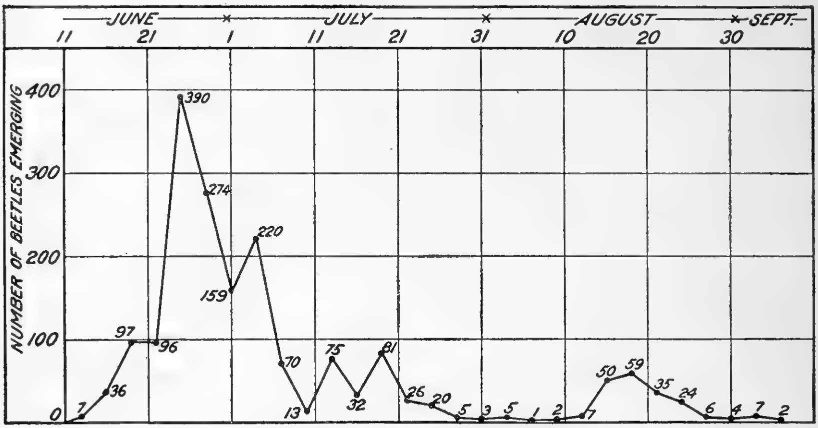


FIG. 21.—Diagram showing normal emergence from soil of beetles of the plum curculio for the season at Barnesville, Ga. (Original.)

At Siloam Springs, Ark., the interval of emergence, June 11 to September 3, includes 84 days. Later miscellaneous records of emerging adults reared from apples, however, were, up to October 23, giving a total emergence interval of 134 days (see fig. 22).

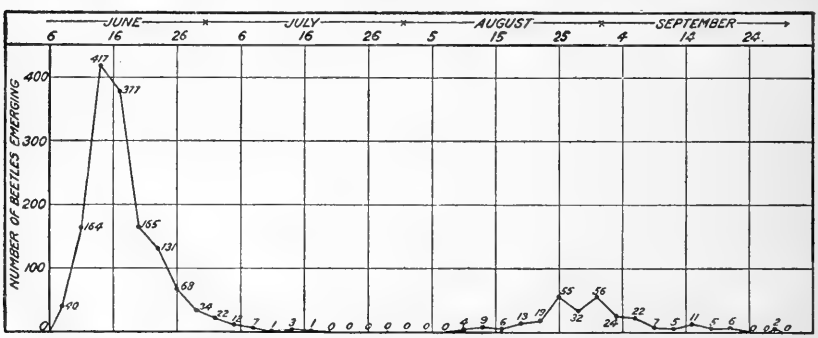


FIG. 22.—Diagram showing normal emergence from soil of beetles of the plum curculio for the season at Siloam Springs, Ark. (Original.)

The Washington, D. C., records show an interval from June 25 to August 21, 57 days. Other miscellaneous records for that locality give adults as early as June 15 and as late as August 30, or 76 days. Unquestionably adults are emerging even later.

The Douglas, Mich., records, as pointed out for the larval emergence data, are manifestly incomplete, especially as regards the latter part of the season. They do, however, show the emergence of beetles from all larvæ from peaches regularly collected throughout the season, as previously shown. The interval here is only 23 days, from August 1 to 23.

Incomplete records from Youngstown, N. Y., give for the earliest beetles July 18 and the latest October 6, a period of 80 days.

At North East, Pa., the first emergence was noted July 15, and beetles were reared in confinement up to August 21, and unquestionably appeared much later. The period observed, however, is 37 days.

In Illinois, as stated by Prof. Crandall, earliest beetles were reared July 17, and continued to emerge until November 7, a period of 113 days. His observations were made on apple, on which fruit the insect would have opportunity for late egg laying, which would not be true in the case of peaches and plums in the South. Unquestionably the Illinois records more nearly show the period of emergence for the Northern States where suitable fruit is not at any time wanting. The above data are shown below in tabular form.

Period of emergence of beetles.

	Days.
Georgia—May 22 to Nov. 9	171
Arkansas—June 11 to Oct. 23	134
District of Columbia—June 15 to Aug. 30	76
Michigan—Aug. 1 to Aug. 23	23
New York—July 18 to Oct. 6	80
Illinois—July 17 to Nov. 7	113

PROPORTION OF SEXES.

The proportion of males and females was determined at different times, with overwintering and newly emerged adults.

In a lot of 80 beetles reared in confinement at Washington during June, 1905, 30 were males and 50 females. In another lot reared as above, 21 were males and 45 females. Of 140 adults jarred from trees in May, 1905, at Arundel, Md., and hence overwintering beetles, 70 were males and 70 females.

At Myrtle, Ga., in 1906, of 200 beetles jarred from trees May 14 to 21, 83 were males and 117 females, and of those taken May 22 to 30, 73 were males and 107 females, a total of 180. One hundred beetles reared from various fruits during May and June gave 51 males and 49 females. In a lot of 175 beetles reared from May 28 to August 12, 81 were males and 93 females. In a lot of 840 beetles jarred from peach at Fort Valley, Ga., in 1905, 339 were males and 501 females.

Considering the proportion of sexes of those reared, there are found, of the total 681, 306 males and 375 females, a percentage of females of 55.

Of those jarred from the trees and which had thus passed the winter, there is a total of 1,180, of which 688 are females and 492 males, a percentage of females of 58.3, showing a slight increase in mortality during winter of males over females.

CHOICE OF FOOD BY CURCULIO.

Practically all writers agree that plums are the preferred food of the curculio. Under orchard conditions, where several fruits are present, as apple, plum, peach, etc., taking the season as a whole, the plum is perhaps somewhat more injured than the others. Varieties of plums, especially Japanese sorts, are early to develop fruit, and consequently are first attacked by the beetles, and on these they seem for a while to concentrate. With the development of peaches, apples, and pears, these are also attacked for feeding and egg-laying purposes. In general, however, it is undoubtedly true that plums are the favorite food of the curculio, and are also preferred for oviposition places.

Attempts have been made to obtain data on the fruits preferred by the insect by supplying beetles with various fruits at the same time.

Tests were made by Mr. Girault, May 17, 1905, in which 5 fruits each of plum, peach, quince, and pear were placed in jars and each supplied with 10 curculios. Upon examination, May 20, 72 hours later, results were as follows: On plum, the egg and feeding punctures were so abundant as practically to cover the whole surface of the fruit; on peach there were numerous punctures, but they were less abundant than on plum; on pear there were no punctures on fruit, but a few were on the fruit stems; on quince no punctures were seen on fruit, but a few were on fruit stems. Expressed in percentages of injury, plum would be 100, peach 50, pear 10, and quince 10.

Mr. J. H. Beattie placed 100 beetles in a jar containing foliage of peach, plum, pear, and quince. Two days later peach leaves had been riddled by feeding; plum leaves were moderately eaten; the quince showed a few feeding marks, while the pear foliage had not been touched.

June 7, 1906, 12 beetles were confined with two large Elberta peaches and five wild plums. After 12 hours, punctures were noted as follows: On plum, egg punctures 37, feeding punctures 30; on peach, no feeding or egg punctures found.

April 23, 1906, 15 curculios were confined under a jar with three fruits each of apple, peach, wild plum, pear, and cherry. The results

gave a preference of fruit, as shown by feeding and egg punctures, in the following order: Apple, peach, plum, cherry, and pear. Further data are given in Table XLIX.

TABLE XLIX.—*Attractiveness of different fruits to the plum curculio.*

Lot I.			Lot II.			Lot III.			Lot IV.		
Dates.	Punctures.		Dates.	Punctures.		Dates.	Punctures.		Dates.	Punctures.	
	Apple.	Peach.		Apple.	Peach.		Apple.	Plum.		Apple.	Plum.
May 1....	5	5	May 13..	10	10	May 20..	5	5	May 28..	5	5
2....	9	11	14..	10	11	21..	9	11	29..	10	10
3....	13	7	15..	8	12	22..	12	8	30..	10	10
4....	13	7	16..	11	9	23..	12	8	31..	5	15
5....	14	6	17..	11	9	24..	12	8	June 1...	8	12
6....	13	7	18..	11	7	25..	10	10	2...	13	7
7....	17	3	19..	10	10	26..	8	14	3...	11	9
8....	10	....				27..	7	3	4...	5	5
Total.	94	46	Total.	71	68	Total.	75	67	Total.	67	73

A total of 165 punctures is shown for apple, as against 114 on peach, and a total for apple of 142 against 140 on plum.

The preference of the curculio for smooth fruit is shown by an experiment by Mr. Girault in 1906. In a jar were placed 20 beetles, 8 males and 12 females, which were supplied on several successive days for four-hour periods, with 3 normal peaches and 3 peaches from which the fuzz, or pubescence, had been removed. The results are as follows:

TABLE L.—*Showing preference of plum curculio for smooth versus fuzzy peaches. Myrtle, Ga., 1906.*

Dates.	Fruit No.	Normal, with pubescence.			Pubescence removed.		
		Egg punctures.	Egg punctures with eggs.	Feeding punctures.	Egg punctures.	Egg punctures with eggs.	Feeding punctures.
Apr. 20	1	....	....	2	16	13	2
20	2	1	1	2	15	9	4
20	3	....	....	4	11	7	3
21	4	....	....	....	1	1	5
21	5	....	....	....	11	10	2
21	6	....	....	1	13	12	6
22	7	....	....	1	11	10	9
22	8	....	....	2	13	11	7
22	9	....	....	1	8	8	5
23	10	2	1	3	4	3	5
23	11	....	....	1	9	9	5
23	12	....	....	3	4	4	3
Total	....	3	2	20	116	97	56

A total of 3 egg and 20 feeding punctures is shown on the normal fuzzy fruit as compared with 116 egg punctures and 56 feeding punctures on fruit from which the hairs had been removed.

EXTENT OF FEEDING OF THE RESPECTIVE SEXES.

The extent to which feeding is done by the respective sexes of the curculio during their lives is shown in Table LI. Individuals of each sex were separately confined and each beetle supplied daily with 4 wild plums, examinations of the fruit being made daily.

TABLE LI.—*Extent of feeding of each sex of the plum curculio during the season, Myrtle, Ga., 1906.*

Dates.	Feeding punctures by males.								Feeding punctures by females.			
	Beetle No. 1.	Beetle No. 2.	Beetle No. 3.	Beetle No. 4.	Beetle No. 5.	Beetle No. 6.	Beetle No. 7.	Beetle No. 8.	Beetle No. 1.	Beetle No. 2.	Beetle No. 3.	Beetle No. 4.
Apr. 16	3	4	......	4	1	1	2	3	13	12	8	7
17	3	4	3	2	1	1	......	2	3	5	4	4
18	2	4	2	2	2	......	1	2	5	4	5	5
19	3	2	2	3	1	......	......	2	8	2	5	3
20	2	1	......	2	1	1	2	......	1	4	3	6
21	8	7	6	6	1	2	1	1	2	5	3	13
22	1	2	3	5	1	1	3	1	8	2	3	8
23	2	1	2	1	1	1	3	2	2	2	3	3
24	1	1	......	3	1	1	2	......	1	5	4	1
25	4	4	2	3	1	......	1	......	5	......	4	6
26	4	5	11	4	3	2	1	1	4	4	5	4
27	5	1	4	3	2	2	1	1	5	3	8	11
28	2	2	5	2	3	1	2	1	3	5	8	3
29	1	2	5	4	1	1	2	......	12	4	3	8
30	......	1	3	2	2	1	1	1	2	3	8	4
May 1	2	3	4	5	......	1	4	3	1	2	2	5
2	4	5	6	3	......	1	1	......	7	6	8	3
3	1	2	10	(1)	......	1	3	1	8	8	19	11
4	3	3	5	......	1	1	3	2	3	5	9	1
5	2	3	1	......	......	1	......	1	2	......	2	3
6	2	1	5	......	1	......	2	......	2	8	3	3
7	2	5	2	......	7	1	2	1	3	4	1	1
8	1	1	3	......	2	2	3	2	4	5	8	......
9	3	3	2	......	......	1	2	2	8	5	6	3
10	2	1	2	......	3	1	......	......	1	5	1	2
11	3	1	1	......	2	1	1	3	5	5	2	2
12	1	4	1	......	1	2	2	2	6	5	2	2
13	1	3	1	......	1	1	......	......	5	6	3	3
14	3	4	2	......	1	1	2	1	6	7	10	3
15	7	7	1	......	1	......	......	2	6	4	3	1
16	3	2	4	......	4	1	2	......	4	4	4	7
17	3	2	3	......	5	......	1	7	4	8	5	4
18	5	3	5	......	6	1	3	2	6	4	8	1
19	2	2	3	......	4	4	2	......	9	4	4	6
20	2	2	4	......	1	......	......	5	4	12	13	14
21	1	3	1	......	2	1	......	1	4	6	10	3
22	5	1	3	......	5	2	2	......	5	6	5	2
23	2	1	2	......	5	......	2	2	......	7	2	2
24	1	1	......	......	......	3	1	1	6	4	11	2
25	1	4	2	......	1	1	......	......	4	5	9	7
26	4	3	4	......	2	......	2	2	6	12	2	6
27	3	4	8	......	5	1	3	3	7	14	6	13
28	1	7	1	......	3	1	1	2	5	7	3	3
29	5	5	5	......	1	2	2	2	4	6	3	2
30	1	2	5	......	1	6	3	1	7	8	1	4
31	5	1	7	......	1	3	2	......	5	2	1	3
June 1	4	4	6	......	5	3	4	......	2	1	......	2
2	1	8	2	......	2	4	1	7	2	4	2	2
3	1	6	10	......	4	1	2	3	5	4	3	2
4	1	5	3	......	5	1	1	......	4	6	4	8
5	4	3	......	......	......	3	3	3	4	3	2	3
6	4	2	6	......	......	2	2	3	5	1	3	4
7	5	4	2	......	......	......	......	2	3	1	2	7
8	3	......	6	......	6	1	1	3	5	1	7	4
9	2	1	2	......	......	2	5	(2)	4	3	......	2
10	6	......	4	......	4	1	1	......	4	4	......	3
11	......	......	......	......	2	2	1	......	4	4	......	16
12	......	......	......	......	......	......	......	......	5	8	......	14
13	......	......	......	......	......	......	......	......	4	8	......	13

[1] Died. [2] Escaped.

TABLE LI.—*Extent of feeding of each sex of the plum curculio during the season, Myrtle, Ga., 1906*—Continued.

Dates.	Feeding punctures by males.								Feeding punctures by females.			
	Beetle No. 1.	Beetle No. 2.	Beetle No. 3.	Beetle No. 4.	Beetle No. 5.	Beetle No. 6.	Beetle No. 7.	Beetle No. 8.	Beetle No. 1.	Beetle No. 2.	Beetle No. 3.	Beetle No. 4.
June 14									22	2	1	8
15									22	7	1	6
16									7	8	2	5
17									8	4		3
18	4	3	1		6	3	8		2	7	2	4
19									19	10		5
20									15	4		9
21									3	8	1	9
22		3	5		1	1			3	5	1	5
23									8	2	4	8
24									5	2	2	10
25									3			3
26									1	2		
27									3	2	5	2
28	(1)									(2)	(2)	
29												
30												
July 1		6	7		1	1						
3							(1)		4	6	1	4
6						(1)			3		5	
7		4	5		3							
9									3			
12									1			
17										(1)		
18					(1)							
19											(1)	
20			(1)									
30		8										
31									(1)			
Aug. 4												(1)
7		(1)										
Total	157	186	210	54	127	81	102	86	404	361	288	369

[1] Died. [2] No record.

The individual records show that the females feed more actively than the males. Most of the males had practically ceased feeding by June 11, although the females continued to feed freely during the rest of the month. The average number of feeding punctures per male, excluding No. 4, is 135.55, as compared with the average of 355.50 for each female.

OPERATION OF EGG LAYING.

The process of egg laying of the plum curculio has excited the interest of many observers, and it has been frequently described. There is much variation in the statements as to time occupied, sequence, and relative time of the various acts, etc. Many writers have not distinguished at all the separate steps involved, as, for example:

As soon as the plums, peaches, cherries, and apples are set the curculio commences operations, imprinting the familiar crescent and placing an egg inside.

Riley's account of oviposition is, however, much more complete, as follows:

That the egg is deposited in the following manner, the whole process requiring about five minutes: Having taken a strong hold on the fruit, the female makes a minute cut with the jaws, which are at the end of her snout, just through the skin of the fruit, and then runs the snout under the skin to the depth of one-sixteenth of an inch, and moves it back and forth until the cavity is large enough to receive the egg it is to retain. She next changes her position, and drops an egg into the mouth of the cut; then, veering round again, she pushes it by means of her snout to the end of the passage, and afterwards cuts the crescent in front of the hole so as to undermine the egg and leave it in a sort of flap, her object apparently being to deaden this flap so as to prevent the growing skin from crushing the egg, though Dr. Hull informs me that he has repeatedly removed the insect as soon as the egg was deposited and before the flap was made, and the egg hatched and the young penetrated the fruit in every instance.

Prof. J. M. Stedman also described the process:

In making punctures for the purpose of depositing eggs, the females also eat the tissues of the apple, and this is probably the reason why during the egg-laying season they do not make as many purely feeding punctures as they do earlier and later in the season. The female first eats a small hole through the skin and then eats the pulp back about one-sixteenth of an inch, thus making a small cylindrical hole, usually quite parallel to the skin. She then turns around and deposits an egg in this hole, which is just large enough to receive the egg nicely. Having accomplished this, she then eats the tissue while cutting a small crescent-shaped hole through the skin and into the pulp so as to partly surround and partly undermine the egg.

In Prof. Crandall's studies many attempts were made to secure data on the entire operation, but owing to the difficulties of so doing, three instances only from start to finish were observed, as follows:

In the first observation, the female moved about the apple for several seconds, keeping the end of her beak in contact with the surface, as if seeking a favorable spot. When the exact spot was decided upon, the minute jaws at the end of the snout began a rapid movement which quickly made an opening through the skin. This opening was no larger than necessary for admission of the tip of the beak. No skin was removed; it was simply torn and thrust aside to give access to the pulp below. Later, as the excavation proceeded, the broken skin was seen as a sort of fringe around the beak at the surface of the fruit. As soon as excavation in the pulp was commenced, the beak was deflected backward so that the work was carried on under the insect, just beneath the skin and nearly parallel with the surface. As the work advanced, the opening through the skin became slightly enlarged by lateral motions of the beak. The pulp was all eaten as excavated. During the process the beak was not once withdrawn, nor was there any cessation of motion. When the excavation of the cavity was completed the beak was withdrawn by a quick motion, the insect turned about, adjusted the tip of the abdomen to the opening and deposited an egg, which was forced to the extremity of the excavation by the ovipositor. The insect now rested without motion for two minutes; then, turning again, proceeded to cut the crescent in front of the egg. This crescent puncture was not wholly a separate puncture, but, starting in the original opening through the skin, was cut laterally in either direction, partly by the jaws and partly by crowding the beak first one way and then the other. The direction of the beak was but little deflected from the perpendicular and the cut was made as deep as the length of the beak would allow. The pulp torn

away in making the crescent was eaten, just as was done in excavating the egg cavity. The crescent completed, the insect walked away, drew the legs closely under the body, and settled down, apparently to sleep. The time occupied in the process described was distributed as follows:

	Minutes.
Excavating egg cavity	9
Deposition of egg	1
Rest	2
Cutting the crescent	3½
Total	15½

The egg cavity was cylindrical, with a rounded bottom, and by measurement was found to be 0.04 inch in depth. The egg when deposited very nearly filled the cavity.

The second observation of the complete process was nearly identical with the one described. The insect spent no time in choosing the exact spot, but went to work at once. It worked in a more leisurely way and did not excavate as deep an egg cavity. Eleven minutes were spent on the cavity, 2 minutes in depositing the egg, 2 minutes in rest, and 4 minutes in cutting the crescent, a total of 19 minutes. The egg cavity measured 0.035 inch in depth and was completely filled by the egg. On completion of the process the insect moved a short distance and immediately began a second cavity.

Essential differences from procedure in the two preceding cases were noted in the third complete observation. Excavation of the egg cavity was the same, except that it was deeper in the pulp and of greater depth. After depositing the egg the beetle turned and with her beak worked the egg back to the bottom of the cavity. Then she began tearing off bits of skin and pulp, which were carefully packed in, above the egg, until the cavity was full. Following this, the crescent was cut in much the same manner as in the preceding cases. Then she appeared to make a final inspection, and added some further packing above the egg. Finally the work appeared to be satisfactory and she walked away and began a second puncture. The time consumed in this process was longer than in the others, and was divided as follows:

	Minutes.
Excavating egg cavity	12
Depositing egg	1½
Placing the egg with the beak	2
Packing the cavity	4
Cutting the crescent	4
Finishing touches	3
Total	26½

Mr. Johnson observed the operation of egg laying in 1905 at Youngstown, N. Y., in a Niagara plum, from which the calyx had recently fallen. The excavating of egg cavity, placing of egg, packing of cavity, and cutting the crescent was done without a pause and occupied 10 minutes.

According to the observations of Mr. J. H. Beattie at Fort Valley, Ga., in 1905, a beetle was occupied 1 minute in making the egg cavity in a plum, after which, turning around, it deposited an egg in about 5 seconds, a few seconds more being required in pushing the egg into the cavity. However, in cutting the crescent 6 minutes were occupied, a total of a little more than 7 minutes.

Mr. Girault observed a beetle at Myrtle, Ga., May 7, throughout the entire operation. This individual had been previously starved and was furnished with a fresh wild plum upon which it climbed at 4.36 p. m., settling on the side. It carefully examined the surface of the fruit before beginning oviposition, as follows:

	Minutes.
Egg cavity begun 4.43.	
Egg cavity finished 4.51	8
Egg deposited 4.51–1$\frac{3}{4}$	$\frac{3}{4}$
Egg pushed in cavity 4.51$\frac{3}{4}$–2$\frac{1}{4}$	$\frac{1}{2}$
Packing egg cavity 4.52$\frac{1}{4}$–4$\frac{1}{2}$	2$\frac{1}{4}$
Began crescent 4.55	
Crescent finished 5.08	13
Total	24$\frac{1}{2}$

During the process the body was in an extended position, legs well out grasping the fruit, and while excavating the cavity the body was at an angle of about 45°. Difficulty was evidenced in holding to the fruit. The tarsi were continually being lifted and extended, and applied to the fruit, and this was followed by a drawing motion, to engage the claws if possible. The antennæ were motionless, the scape lying alongside the rostrum.

At Barnesville a beetle was observed ovipositing on plum, April 11. Its time record was as follows:

	Minutes.
Beak inserted 9.47.	
Beak withdrawn and ovipositor inserted 9.49	2
Ovipositor removed 9.49$\frac{1}{2}$	$\frac{1}{2}$
Packing cavity, until 9.52	2$\frac{1}{2}$
Began cutting crescent 9.52	
Crescent completed 11.07	
Actual time occupied in cutting	36
Beetle rested 6 times while cutting crescent, a total of	39
Total interval	80

Also at Barnesville a beetle was observed April 20 ovipositing in young peach. At 9.30 the hole was started in fuzz, the beak being worked down full length. At 9.41$\frac{3}{4}$ beak was withdrawn and the ovipositor inserted. The ovipositor was withdrawn at 9.42$\frac{1}{2}$ and the egg pushed down with the beak. The beetle withdrew at 9.46 without filling the hole in the fuzzy covering of the peach as usual, the total time being 16 minutes.

Another beetle, ovipositing on plum, inserted the beak at 9.08, the egg cavity was finished and ovipositor inserted at 9.09$\frac{1}{2}$, and the ovipositor was removed at 9.10. After packing the egg cavity the crescent was begun, which was finished by 9.28, a total of 20 minutes for the entire process.

EGG AND FEEDING PUNCTURES: POSITION ON FRUIT AND VARIATION IN FORM.

The position of the egg puncture on the young fruit, as would be surmised from observations on the process of oviposition, is determined in a general way by the part affording the beetles the best anchorage for their feet during the work of excavating the puncture and crescent. This position will vary according to the age of the fruit, and also according to the kind, as whether plum, peach, apple, or other species. Some data were secured by Messrs. Girault and Rosenfeld as to the location of egg and feeding punctures, which are set forth in Tables LII to LIV. In the case of the peach, it proved to be difficult to separate positively the two forms of punctures, and these are considered under the same heading.

TABLE LII.—*Location of egg and feeding punctures of the plum curculio on wild plums, Myrtle, Ga., 1906.*

Dates of examinations.	Fruits examined.		Egg punctures.	Location of egg punctures on fruit.					Feeding punctures.	Location of feeding punctures on fruit.				
	Number.	From—		Apex.	Base.	Center of side.	Apical third.	Basal third.		Apex.	Base.	Center of side.	Apical third.	Basal third.
Apr. 9	200	Tree	22	22	....	....	....	....	11	2	....	4	3	2
13	100	...do	48	45	....	....	2	1	21	8	....	6	6	1
20	100	...do	55	49	....	....	3	3	3	....	1	1	1	....
22	50	Ground	43	32	1	3	4	3	14	1	1	4	....	8
30	50	Tree	76	36	2	5	14	19	5	3	....	1	....	1
30	50	Ground	101	45	8	10	21	17	10	....	....	....	1	9
May 8	50	...do	52	13	2	4	8	25	6	....	....	....	....	6
8	50	Tree	73	4	2	13	3	51	4	....	1	1	....	2
31	50	Ground	102	17	14	20	5	46	5	....	2	1	....	2
31	50	Tree	48	11	8	3	8	18	7	....	2	1	....	4
June 6	50	...do	62	8	14	5	1	34	3	....	1	1	....	1
6	25	Ground	58	2	7	3	1	45	6	....	....	1	....	5
11	50	Tree	42	2	18	3	2	17	3	....	....	....	2	1
Total	875	....	782	286	76	69	72	279	98	14	8	21	13	42

TABLE LIII.—*Location of egg and feeding punctures of the plum curculio, Myrtle, Ga., 1906.*

KIEFFER PEAR.

Dates of examinations.	Fruits examined.		Egg punctures.	Location of egg punctures on fruit.					Feeding punctures.	Location of feeding punctures on fruit.				
	Number.	From—		Apex.	Base.	Center of side.	Apical third.	Basal third.		Apex.	Base.	Center of side.	Apical third.	Basal third.
Apr. 9	200	Tree	16	....	....	8	2	6	9	1	....	5	3	....
9	160	Ground	3	....	....	2	....	1	5	....	....	2	2	1
13	100	Tree	20	....	....	13	3	4	15	....	....	11	2	2
13	100	Ground	7	....	....	7	....	....	8	2	....	6	....	....
20	50	Tree	40	....	....	24	4	12	3	....	....	3	....	....
20	50	Ground	9	....	3	3	....	3	1	....	....	1	....	....
May 2	50	Tree	26	3	3	11	6	3	8	....	....	6	....	2
4	50	Ground	22	....	1	12	7	2	12	1	....	5	3	3
31	50	Tree	16	....	2	8	2	4	16	2	2	6	1	5
Total	810	....	159	3	9	88	24	35	77	6	2	45	11	13

TABLE LIII.—*Location of egg and feeding punctures of the plum curculio, Myrtle, Ga., 1906*—Continued.

APPLE.

Dates of examinations.	Fruits examined.		Egg puncturs.	Location of egg punctures on fruit.					Feeding punctures.	Location of feeding punctures on fruit.				
	Number.	From—		Apex.	Base.	Center of side.	Apical third.	Basal third.		Apex.	Base.	Center of side.	Apical third.	Basal third.
Apr. 13	100	Tree	2	....	....	1	....	1	10	....	5	4	1	....
22	50	...do	15	....	4	6	....	5	8	....	....	3	....	5
May 5	50	...do	47	1	4	26	7	9	13	....	9	1	....	3
Total	200		64	1	8	33	7	15	31	....	14	8	1	8

TABLE LIV.—*Location of egg and feeding punctures of the plum curculio on peach, Myrtle, Ga., 1906.*

Dates of examination.	Fruits examined.		Fruits punctured.	Egg and feeding punctures.	Location of egg and feeding punctures on fruit.					Remarks.
	Number.	From—			Apex.	Base.	Center of side.	Apical third.	Basal third.	
Apr. 9	200	Tree	4	3	....	1	1	1	....	All feeding punctures.
9	200	...do	31	42	2	7	11	8	14	4 egg punctures.
13	100	...do	20	35	3	10	7	3	12	5 egg punctures.
14	100	...do	29	63	3	3	15	4	38	21 egg punctures.
20	50	...do	19	38	2	2	20	7	7	4 egg punctures.
26	50	...do	46	111	1	4	66	15	25	Egg and feeding punctures not separated.
28	50	Ground	46	126	12	12	60	22	20	Do.
May 7	50	Tree	32	122	6	10	73	11	22	25 egg punctures.
7	50	Ground	37	70	1	21	15	9	24	Egg and feeding punctures not separated.
22	50	Tree	21	36	2	6	14	4	10	Do.
22	50	Ground	34	63	7	12	24	15	5	Do.
28	50	Tree	23	45	2	6	17	11	9	Do.
28	50	Ground	35	84	3	11	46	10	14	Do.
June 8	50	Tree	39	122	5	12	35	35	35	Do.
8	50	Ground	43	130	20	27	30	43	10	Do.
Total	1,150		459	1,090	69	144	434	198	245	

In the case of wild plums the tendency, early in the season when the fruit is small, to oviposit on the apex of the fruit is very marked. Thus to April 30, 55.8 per cent of all punctures were there located. After this date, by which time the fruit had become of some size, the egg punctures were to be found more often on the basal third. For the period of observations April 9 to June 11 the majority of feeding punctures was also found on the basal third. The distribution for the season of the totals is indicated in the table (Table LII).

As regards the Kieffer pear, there was always a majority of the egg punctures on the side, the basal third of the fruit being next preferred, which distribution also holds good for the feeding punctures.

Observations on apples were quite limited, but also indicate a preference for the side for egg laying, while feeding punctures were about equally distributed over the base, side, and basal third, indicating a preference in feeding for the lower part of the fruit.

At Barnesville, Ga., in 1910 it was observed that during the first 10 days or 2 weeks of oviposition on the peach no punctures were made through the skin. Owing to the small area of the fruit surface at this stage of growth the layer of fuzz is very thick, and it seems that the snout of the beetle is not long enough to make the normal punctures when working through so great a depth of fuzz. Punctures were made in the fuzz down to the skin, which was usually abraded somewhat, causing a small area of russet to develop. The eggs were placed in contact with the fruit skin and the hole above them filled with loose fuzz. These punctures were conspicuous by reason of the difference in refraction between the normally erect pubescence and that which had been packed haphazard into an egg puncture.

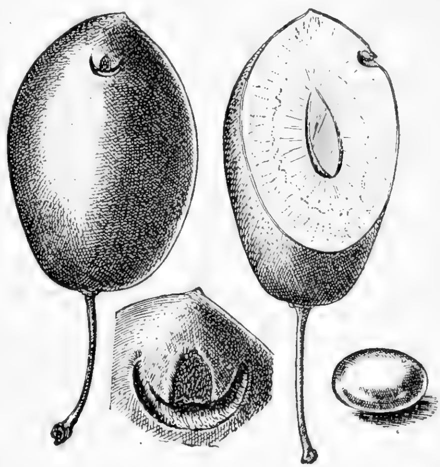


FIG. 23.—The normal plum-curculio puncture; egg at right. (Original.)

For peach the consolidated records of egg and feeding punctures for the season show a distinct majority in favor of the side of the fruit, with the basal third next in rank.

The normal egg puncture consists of the egg cavity and a crescentic cut, as shown in figure 23. The egg cavity is cylindrical, about 0.04 inch deep, and the crescentic cut is in the form of an arc. The egg cavity, and especially the crescent, may vary widely. The crescent, however, if it is to serve the purpose intended, is cut deeply and extends back under the egg cavity. (See fig. 23.) Externally the modification of the typical puncture usually consists of a shortening of the horns of the crescent, often to such an extent that the crescentic cut appears as a short straight line. Also the position of the crescent when of normal form varies much in relation to the egg cavity, which may be considerably to one side. These variations appear not to be due to faulty instinct, but to the different conditions under which the work is accomplished. Punctures made by individual beetles in con-

finement present many variations; as already explained, the beetles in making the punctures derive much of the necessary force from the legs, and the feet must be firmly anchored. That they often have trouble to secure a good footing is clear from observations on the beetles at work. In fact, the attempt at a given point on smooth and tough skinned fruits, as apples and plums, is not infrequently abandoned and other locations sought. Young apples and peaches covered with pubescence and pears with roughened skin afford good anchorage for the feet. As the apples grow, however, the skin becomes smooth and beetles have trouble in puncturing the tough skin and abnormal punctures are frequent. In the case of wild plums detailed observations indicate that difficulty is often experienced by the beetles, as shown by variations in the egg puncture. Thus, in a study of 200 fruits which averaged about 12.75 mm. in greatest transverse diameter and each bearing an egg puncture, 102, or 51 per cent, of the punctures were normal. In 75 cases the crescent was short and almost a straight line and was entirely absent in 23 cases, the egg cavity only being present. The following records of the activities of 30 pairs of beetles in egg laying and feeding on plums during the night of May 12 are of interest in this connection. There were 121 crescentic punctures with eggs and 51 such punctures without eggs; 13 cavities with eggs were unaccompanied by crescents, and two eggs were found in one egg cavity. About 324 feeding punctures were present.

The variation in position of the crescentic cut was found in 50 plums examined to be as follows: Normal, 18; with crescent but little curved, 10; with crescent short and straight, 12; and the crescent was absent in 10. The same specimens showed a variation in relative position of crescent and egg cavity as follows: Egg cavity central to crescent, 20; slightly to right, 8; slightly to left, 5; on center of right, 4; on center of left, 3; crescent absent, 10.

RELATIVE NUMBER OF FEEDING AND EGG PUNCTURES.

The relative abundance of feeding and egg punctures was several times noted. Table LV gives data from three localities. The fruit used at Siloam Springs, Ark., was apple; at Washington, D. C., plum; and at Myrtle, Ga., peach. The date of death of the respective sexes was not determined for Arkansas. In the Washington records the dates are for both sexes, and the Georgia records give dates of death of each sex for each pair.

TABLE LV.—*Comparison of number of feeding and egg punctures of the plum curculio from various localities.*

Pair No.	Siloam Springs, Ark., 1908.			Washington, D. C., 1905.		
	Feeding punctures.	Egg punctures.	Length of life.	Feeding punctures.	Egg punctures.	Length of life.
1	549	61	May 13 to Sept. 15	273	289	May 11 to July 3–6.
2	477	57	May 13 to July 28	311	616	May 11 to Aug. 28.
3	85	16	May 13 to May 29	165	131	May 11 to June 18.
4	261	25	May 13 to June 28	280	350	May 11 to July 7.
5	195	23	May 13 to July 8			
6	295	20	May 13 to Sept. 9			
7	267	60	May 13 to July 31			
8	39	7	May 13 to May 24			
9	409	31	May 13 to Aug. 20			
10	295	15	May 13 to July 17			
Total	2,872	315		1,029	1,386	

Pair No.	Myrtle, Ga., 1906.			Male died—
	Feeding punctures.	Egg punctures.	Length of life.	
1	160	138	Apr. 6 to July 30	May 18
2	110	29	Apr. 6 to June 5	July 29
3	217	191	Apr. 6 to July 26	July 24
4	147	79	Apr. 6 (?)	July 20
5	152	118	Apr. 6 to Aug. 9	July 18
6	146	44	Apr. 6 to June 26	June 2
7	150	82	Apr. 6 to June 18	June 18
8	211	133	Apr. 6 to Aug. 10	Aug. 20
Total	1,293	814		

It will be noted that in two instances feeding punctures considerably outnumbered the egg punctures. For Arkansas the ratio is about 9 to 1, and for Georgia about $1\frac{1}{2}$ to 1, indicating considerably less feeding on peaches in proportion to egg laying than in the case of apples. The Washington records show a larger number of egg than feeding punctures, but these specimens were kept under temperature conditions abnormally high, which probably stimulated oviposition, as elsewhere stated.

ACTIVITY OF THE BEETLES IN EGG LAYING AND FEEDING, BY DAY AND BY NIGHT.

Information on the relative activity during day and night of the beetles in oviposition and in feeding is meager. Riley [1] states that the curculio is nocturnal rather than diurnal, as regards the period of flight, and affirms that it is far more active at night than during the day. He further adds that, with the exception of such females as are engaged in egg laying, most of the curculios rest during the day, sheltered by the foliage or branches of the tree or convenient trash or the ground.

[1] Third Missouri Report, p. 14.

In the article on the curculio by Riley and Howard,[1] it is stated that although the females lay their eggs chiefly during the daytime, the insect is essentially nocturnal, flying freely during warmer nights and only seeking shelter when the nights are cold. Prof. J. M. Stedman[2] says that the females may deposit eggs during a part of the day and part of the night, or all day if the weather be cloudy, but do not appear to enjoy egg laying during the heat of the day. They frequently drop to the ground during the middle of the forenoon, hiding until late in the afternoon, when they fly to the trees and again begin work.

In connection with other observations on beetles in confinement, Prof. Crandall determined the number of eggs and feeding punctures during day and night, respectively, which data it would seem could be fairly held to indicate their general activity under normal conditions. Of the total of 5,631 feeding punctures recorded, 2,594 were made during the day and 3,037 at night, a balance of 443 in favor of night feeding. In regard to oviposition, of the total eggs recorded (1,954), 1,037 were laid during the day and 917 at night (6.30 p. m. to 8.30 a. m.), a balance of 120 in favor of the day for oviposition.

Records made in 1906, at Myrtle, Ga., by Messrs. Girault and Rosenfeld bear out the conclusions evident from Crandall's observations. April 9, beetles were captured by jarring peach trees and when found mating later in the day were separately confined in jars with wild plums. Beginning April 12, observations were made at 9 a. m. and 9 p. m. each day until June 29, except in the case of pair No. 5, as shown in detail in Table LVI. After June 29 the records are not complete.

TABLE LVI.—*Comparative activity during day and night of five pairs of the plum curculio in feeding and oviposition, Myrtle, Ga., 1906.*

Dates of examination.	Pair No. 1.				Pair No. 2.				Pair No. 3.				Pair No. 4.				Pair No. 5.			
	Eggs.		Feeding punctures.		Eggs.		Feeding punctures.		Eggs.		Feeding punctures.		Eggs.		Feeding punctures.		Eggs.		Feeding punctures.	
	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.
Apr. 10	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
11	4	....	17	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
12	4	2	8	7	....	....	2	1	....	....	6	5	....	....	4	7	....	....	....	11
13	5	....	6	8	1	....	1	2	....	....	5	4	1	....	7	6	....	2	27	13
14	....	4	7	3	....	....	1	1	....	7	7	3	1	4	8	4	3	2	10	2
15	....	1	2	2	....	3	1	5	4	1	1	2	1	3	3	2	....	1	7	5
16	3	2	5	2	1	4	2	....	4	5	2	1	1	1	3	1	....	1	6	2
17	3	4	3	3	2	3	3	5	2	4	....	1	2	4	1	3	1	....	8	9
18	1	2	5	2	....	2	4	....	1	3	3	3	....	2	5	....	....	2	5	2
19	2	2	3	2	2	1	6	....	....	4	2	1	....	5	2	....	....	....	3	2
20	4	1	4	1	1	2	5	3	....	3	6	4	....	4	4	3	....	2	2	3
21	....	10	4	1	2	4	8	5	1	2	4	1	....	1	5	3	....	....	10	2
22	1	6	2	6	3	3	6	3	....	1	3	5	....	1	2	2	....	....	1	2
23	3	2	1	1	2	1	4	....	1	2	2	....	....	2	1	4	....	....	3	....
24	1	2	....	4	....	4	3	....	1	3	3	3	....	....	5	3	2	....	2	3
25	3	5	....	6	1	....	2	6	....	....	3	....	....	1	2	....	1	1	....	3
26	6	....	3	2	3	1	6	4	....	2	5	....	2	4	2	7	1	1	4	3
27	4	5	7	5	5	4	7	4	2	....	6	3	....	2	2	2	2	4	6	5
28	2	7	2	5	2	2	3	6	3	2	....	2	....	....	3	1	1	1	....	2

[1] Rept. Comm. Agr. for 1888, p. 61.

[2] Bul. 64, Missouri Station, p. 16.

TABLE LVI.—*Comparative activity during day and night of five pairs of the plum curculio in feeding and oviposition, Myrtle, Ga., 1906*—Continued.

Date of examination.	Pair No. 1.				Pair No. 2.				Pair No. 3.				Pair No. 4.				Pair No. 5.			
	Eggs.		Feeding punctures.		Eggs.		Feeding punc. tures.		Eggs.		Feeding punctures.		Eggs.		Feeding punctures.		Eggs.		Feeding punctures.	
	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.
Apr. 29	8	2	5	6	4	6	3	2	2	....	....	1	....	1	6	4	2	5	3	4
30	1	7	2	5	3	4	....	3	1	1	2	5	3	1	4	3	3	3	1	5
May 1	....	4	6	8	4	4	10	2	5	1	3	3	2	3	5	1	2	4	4	5
2	5	3	12	8	3	3	3	7	2	....	3	5	1	2	4	3	2	5	2	4
3	4	4	5	3	1	2	4	2	3	2	3	2	3	1	4	2	3	6	4	1
4	5	2	3	5	3	2	2	1	4	2	2	2	2	2	2	2	1	1	4	3
5	1	3	6	2	2	1	1	2	2	1	3	2	2	....	2	3	2	....	1	2
6	4	5	2	5	....	3	2	1	4	2	....	3	3	4	5	4	....	....	2	3
7	5	3	4	3	2	1	6	4	1	2	1	2	2	1	3	....	....	1	4	1
8	1	4	1	3	1	2	1	2	2	3	2	1	2	....	1	1	....	....	6	1
9	2	1	3	3	2	1	1	5	1	1	1	....	1	1	1	1	....	....	....	1
10	2	3	4	1	1	3	1	....	2	1	2	....	1	1	3	3	....	....	2	2
11	1	4	9	5	....	1	1	3	2	1	4	3	3	2	3	....	....	....	3	4
12	3	3	4	....	1	2	2	1	1	....	1	1	2	4	6	2	1	....	3	2
13	3	3	1	1	1	2	1	6	....	1	1	1	4	2	3	3	....	2	4	2
14	4	2	3	3	....	3	3	1	1	....	1	1	2	2	6	5	2	1	5	8
15	4	5	3	3	2	2	....	3	1	1	2	2	2	1	5	3	1	....	4	8
16	2	5	10	3	1	5	3	4	3	....	5	2	....	5	3	6	1	1	2	2
17	3	7	9	9	1	3	6	5	....	6	2	1	1	5	3	6	1	2	5	5
18	2	4	7	4	....	....	2	4	1	3	6	4	3	4	3	4	1	1	1	1
19	6	5	12	9	3	3	10	3	2	....	....	1	1	5	9	10	....	3	5	1
20	6	5	7	6	3	3	5	12	1	1	7	1	4	3	6	7	1	4	....	2
21	4	3	4	4	1	3	4	10	1	1	1	2	1	1	5	8	3	4	4	5
22	1	4	2	2	....	2	1	1	....	....	5	....	2	1	2	4	2	6	1	1
23	2	....	3	5	1	....	3	7	....	2	2	1	1	....	3	1	....	3	4	1
24	....	1	....	3	....	2	2	4	....	....	1	1	1	1	4	7	4	1	3	6
25	3	....	3	6	2	1	3	1	....	....	6	1	2	1	8	3	3	4	1	2
26	....	1	6	3	....	3	2	4	....	....	1	3	....	5	4	5	3	3	5	1
27	....	....	1	1	....	....	9	10	1	....	1	5	3	3	4	4	4	4	1	4
28	....	....	2	5	....	3	1	5	....	1	3	3	2	4	5	6	1	3	3	3
29	....	....	3	6	1	....	3	6	1	1	3	1	2	2	2	3	3	2	1	1
30	....	....	5	6	....	....	5	5	2	1	1	5	2	1	5	5	1	4	13	3
31	....	2	7	8	....	1	1	4	....	....	3	6	....	1	7	7	2	3	11	3
June 1	3	....	7	....	1	....	5	6	....	....	5	2	2	....	6	2	4	....	3	2
2	3	3	8	4	....	2	3	4	3	1	2	3	1	....	6	8	1	3	8	3
3	....	2	8	2	....	3	4	6	1	1	2	5	....	....	8	1	2	3	2	4
4	2	1	6	1	2	....	9	8	3	....	2	5	1	1	3	6	1	6	....	1
5	1	2	1	1	1	1	8	9	1	1	3	3	....	....	11	7	2	2	7	6
6	1	3	1	6	1	2	8	7	1	1	3	....	....	1	9	4	5	3	5	9
7	2	1	9	2	....	....	7	1	2	....	2	1	7	....	4	2	2	4	4	5
8	1	....	5	3	1	2	7	6	2	1	4	1	1	....	3	3	1	3	3	4
9	1	1	8	7	2	1	6	....	2	....	3	2	....	....	6	7	2	4	8	2
10	1	1	6	7	....	....	....	1	1	....	....	2	2	....	5	3	3	....	3	....
11	....	1	8	3	1	....	1	2	1	....	....	....	1	....	3	1	5	3	7	8
12	1	3	....	5	....	1	1	....	....	1	....	3	....	1	....	1	20	....	41	....
13	3	....	3	....	....	....	....	....	1	....	2	....	1	....	1	....	....	....	....	....
14	....	2	....	6	....	....	....	2	....	....	1	4	....	2	1	3	....	....	....	....
15	4	3	8	7	....	....	6	2	2	2	4	3	6	....	5	5	....	....	....	....
16	4	....	4	1	....	....	5	....	2	....	2	....	....	2	4	2	....	....	....	....
17	1	....	5	2	....	....	3	1	....	1	4	....	....	....	5	....	....	....	....	....
18	6	1	6	6	....	....	2	1	3	3	5	1	1	1	4	1	....	....	....	....
19	2	....	6	1	....	....	1	....	....	2	....	4	1	....	6	....	....	....	....	....
20	....	....	....	1	....	....	1	....	2	....	4	1	....	....	7	....	....	....	....	....
21	....	4	....	7	....	....	5	4	3	....	2	....	....	1	4	5	....	....	....	....
22	3	2	9	2	....	....	....	....	1	....	2	....	....	....	....	....	....	....	....	....
23	5	4	7	5	....	....	9	....	2	....	5	....	1	....	5	....	....	....	....	....
24	3	....	6	....	....	....	6	....	....	....	5	....	....	....	2	....	....	....	....	....
25	2	4	....	1	2	....	4	4	1	....	3	5	1	....	2	....	....	....	....	....
26	2	3	1	1	....	....	3	4	....	....	4	4	1	1	1	....	....	....	....	....
27	4	....	2	....	1	....	3	....	....	....	6	....	2	....	3	....	....	....	....	....
28	5	2	2	7	3	....	7	....	....	3	....	5	....	....	9	1	....	....	....	....
29	1	4	6	7	2	3	3	8	....	2	....	4	....	1	....	7	....	....	....	....
30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
July 1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3	....	58	....
3	3	....	2	....	....	3	9	13	....	....	....	....	....	....	....	....	....	....	....	....
6	3	....	5	....	2	1	7	6	1	1	7	3	....	....	3	....	14	....	26	....
9	9	....	5	....	5	....	....	....	....	....	....	....	....	....	3	....	....	....	....	....
12	....	....	4	....	....	....	....	....	1	....	1	....	....	....	4	....	....	....	....	....
30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	18	....	....	....
Total	204	197	381	299	92	124	298	271	101	94	219	170	97	115	328	243	143	124	381	210

It will be noted that in the case of each of the five pairs, the number of eggs deposited during the day is greater than the number laid at night. Of the total of eggs laid (1,291), 654 were laid from 9 a. m. to 9 p. m., while 637 were deposited during the balance of the 24 hours, a difference, however, of only 17. A total of 2,800 feeding punctures is recorded, 1,607 being made at night and 1,193 during the day, a difference of 414 in favor of night feeding.

The data suggest, therefore, that the curculio feeds rather more at night than in the day and that egg laying goes on at about an equal rate during night and day.

TIME REQUIRED FOR TRANSFORMATION FROM EGG TO ADULT.

The length of time spent in the fruit and in the soil has been shown separately in Tables XXV to XL. While these data are not entirely comparable, as representing different parts of the season and a variable number of individuals, nevertheless the final averages, when brought together, should give an approximate idea of the time required for the complete life cycle of the curculio. The final averages of time occupied in the fruit and in the soil as detailed are given in Table LVII with time for all stages shown, as determined by adding together these two periods.

TABLE LVII.—*Time required for the complete transformations of the plum curculio (combined data from preceding tables).*

Localities.	Season.	Time spent in fruit (egg and larval stages combined).	Time spent in ground.	Time required for complete transformation.
		Days.	*Days.*	*Days.*
Griggsville, Ill.	1904	20.00	28.24	48.24
Youngstown, N. Y., and North East, Pa.	1905-6	19.68	31.04	50.72
Washington, D. C.	1905-1908	15.52	32.04	47.56
Myrtle, Ga.	1906	17.90	25.15	43.05
Siloam Springs, Ark.	1908	21.74	29.00	50.74
Douglas, Mich.	1910	20.80	36.41	57.21
Barnesville, Ga.	1910	20.73	34.38	54.38
Average		19.48	30.89	50.27

Considerable variation is shown between the averages of time spent in the fruit, and also between the averages of time spent in the ground, for the several localities. The shortest average time in fruit is shown by the 1905 Washington records, 15.52 days, and this is most closely approximated by the Georgia records a year later, namely, 17.90 days. The longest average is from Arkansas, in 1908, with 21.74 days. As regards the average time spent in the ground, the Georgia record for 1906 is lowest, 25.15 days, and the 1910 Michigan records highest, 36.41 days, though closely approximated by the Barnesville records for 1910 of 34.38 days.

The average time required for complete transformation and emergence of beetles, as shown in Table LVII, also varies considerably, but in view of the variations in season and in the localities from which records were obtained are more uniform than had been expected. Thus, between the shortest time, 43.05 days (Georgia, 1906), and the longest, 57.21 days (Michigan, 1910), there is a variation of only 14.16 days. The average time for the complete life cycle from egg to emergence of adult for all localities is 50.27 days.

Complete records were obtained, in the case of a few individuals, of time occupied from deposition of egg to appearance of adult, as shown in Table LVIII. The averages for each locality are based on the total number of life-cycle days. The Barnesville, Ga., records include individuals from eggs laid each month from April to August, inclusive. These are separated in the table so as to show the marked lengthening of the life cycle in the earliest individuals, from eggs laid April 8–14.

TABLE LVIII.—*Showing time required for transformations of the plum curculio from egg to adult. Individual records.*

Localities.	Dates of oviposition.	Individuals.	Beetles emerging in specified days from oviposition.														
			36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Barnesville, Ga.	Apr. 8–14, 1910	91															
Do	May 9–26, 1910	49					1	3	3	8	2	8	4	6	9	4	2
Do	June 16–30, 1910	27		1	2	1	2	1	4	3	3	2	1		2	1	
Do	July 1–30, 1910	177		3	3	11	15	13	12	15	17	13	16	9	9	15	6
Do	Aug. 7–17, 1910	71		1					1	2	1	7	3	5	6	16	7
Total		415		5	5	12	18	17	20	28	23	30	24	20	26	36	15
Youngstown, N. Y.	June 21–24, 1905	10											2	2		2	1
North East, Pa.	June 13–14, 1906	17											2	2	6	1	
Washington, D. C.	May 10–June 10, 1905	33	17	11	4											1	
Myrtle, Ga.	May 7–16, 1906	24				1	4	8	1	2			1		1		
Douglas, Mich.	June 24–July 6, 1910	98												1			
Grand total		597	17	16	9	13	22	25	21	30	23	30	29	25	33	40	16

Localities.	Dates of oviposition.	Individuals.	Beetles emerging in specified days from oviposition.														
			51	52	53	54	55	56	57	58	59	60	61	62	63	64	65
Barnesville, Ga.	Apr. 8–14, 1910	91											2		11	12	26
Do	May 9–26, 1910	49		1													
Do	June 16–30, 1910	27	1		1				1			1					
Do	July 1–30, 1910	177	3	5	4	3		2	1	1		1					
Do	Aug. 7–17, 1910	71	4	3	2	5	3	1	2			1	1				
Total		415	8	9	7	8	3	3	4	1		3	3		11	12	26
Youngstown, N. Y.	June 21–24, 1905	10	1	1									1				
North East, Pa.	June 13–14, 1906	17	3	3													
Washington, D. C.	May 10–June 10, 1905	33															
Myrtle, Ga.	May 7–16, 1906	24	1			1	1				3						
Douglas, Mich.	June 24–July 6, 1910	98	1	1	1	3	19	9	7	4	11	17	8	1	7	2	4
Grand total		597	14	14	8	12	23	12	11	5	14	20	12	1	18	14	30

TABLE LVIII.—*Showing time required for transformations of the plum curculio from egg to adult. Individual records*—Continued.

Localities.	Dates of oviposition.	Individuals.	Beetles emerging in specified days from oviposition.													Total life cycle.	Average length of life cycle.
			66	67	68	69	70	71	72	73	74	75	76	77	78		
																Days.	*Days.*
Barnesville, Ga.	Apr. 8–14, 1910	91	17	8	7	3	..	1	2	..	..	..	..	1	1	5,984	67.23
Do	May 9–26, 1910	49	..	..	..	..	..	..	..	..	..	..	..	..	..	2,327	45.64
Do	June 16–30, 1910	27	..	..	..	..	..	..	..	..	..	..	..	..	..	1,204	44.59
Do	July 1–30, 1910	177	..	..	..	..	..	..	..	..	..	..	..	..	..	7,979	45.06
Do	Aug. 7–17, 1910	71	..	..	..	..	..	..	..	..	..	..	..	..	..	3,511	49.53
Total		415	17	8	7	3	..	1	2	..	..	..	..	1	1	20,995	50.35
Youngstown, N. Y.	June 21–24, 1905	10	..	..	..	..	..	..	..	..	..	..	..	..	..	498	49.80
North East, Pa.	June 13–14, 1906	17	..	..	..	..	..	..	..	..	..	..	..	..	..	832	43.06
Washington, D. C.	May 10–June 10, 1905	33	..	..	..	..	..	..	..	..	..	..	..	..	..	1,220	36.97
Myrtle, Ga.	May 7–16, 1906	24	..	..	..	..	..	..	..	..	..	..	..	..	..	1,086	45.25
Douglas, Mich.	June 24–July 6, 1910	98	..	1	1	..	..	..	..	..	..	..	..	..	..	5,728	58.45
Grand total		597	17	9	8	3	..	1	2	..	..	..	..	1	1	30,359	49.85

The several averages of time for complete transformations in the individual records show a range of from 36.97 to 67.23 days, the former from the insectary records of 1905 at Washington and the latter from Barnesville, Ga., in 1910. There is here a difference of 30.26 days, but it should be borne in mind that the insectary records show a much shorter life-cycle period than normal, by reason of the high temperature under which the insects were reared. The average of all localities is 49.85 days, differing by only a fraction of a day from the average of 50.27 days already shown in Table LVII.

SEASONAL HISTORY.

TIME OF APPEARANCE OF BEETLES IN SPRING.

The curculio is roused from hibernation in spring by about the same temperature conditions required to bring into blossom the various deciduous fruits upon which it subsists. It is a matter of importance, however, to know just when the beetles first appear in orchards with reference to the condition of the trees; as whether before blossoming, during this period, or after the fruit has set. This question has a bearing on the time of making spray applications and of beginning other remedial work, as jarring. Little exact information on this point is to be found in literature. Dr. Tilton (loc. cit., p. 116), writing in 1804, remarks that—

> Early in the spring, about the time when the fruit trees are in blossom, the curculiones ascend in swarms from the earth, crawl up the trees, and as the several fruits advance they puncture the rind or skin with their pointed rostra, and deposit their embryos in the wounds thus inflicted.

Mr. William Bartram, in a paper read in 1789, expressed the belief that the insects appeared when the fruit was half grown or younger,

and Dr. Harris (loc. cit., p. 67) remarks that they begin to sting plums as soon as the fruit is set.

Dr. Fitch (Essay, p. 16), writing in 1860, states that the insects make their appearance on plum trees when the young fruit is about one-third or one-half grown. The question was well investigated by Dr. Trimble (loc. cit., p. 72) in New Jersey in 1864, and frequent jarrings were made beginning May 12, at which time quince trees were in full bloom and green gage plums were just forming. Three beetles were caught from plum on May 13, 1 on May 18, and 10 on May 20 on knots of cherry and plum. Curculio punctures were in evidence on pears and cherries on May 18 and on plum on May 19.

Walsh (Prac. Ent., vol. 2, p. 75) states that the female curculio makes her appearance early in the season, and as soon as the young plums are a little larger than a hazelnut.

According to Dr. Riley (loc. cit., p. 53) the beetles in central Missouri begin to enter orchards during the first days of May, and commence to penetrate the fruit about the middle of the same month, varying with the season, peaches at this time being about the size of a small marble.

Riley (Amer. Ent., vol. 2, p. 131) further states that the curculio commences to puncture peaches when they are the size of small marbles or hazelnuts, though she may be found in the trees as soon as they are in blossom.

This point is not touched upon in the excellent account of this insect by Riley and Howard in the Annual Report of the Commissioner of Agriculture for 1888, though in the colored plate accompanying the article the weevils are shown on a plum twig, the buds of which are not yet expanded.

Lintner (11th N. Y. Rept., p. 122), writing in 1895, says that the plum curculio enters upon the scene at least two weeks before its first crescentic cuts are made in the fruit.

More exact data are presented by Prof. Crandall (loc. cit., p. 495) in his studies of the curculio in Illinois, in 1903 and in 1904. Thus, during the spring of 1903 apple trees were carefully searched at frequent intervals, but no beetles were found until May 10, when they were abundant, appearing to come all at once. Apple buds were opening by April 16, the trees were in full bloom April 22, and the petals had practically all fallen by May 4. The beetles, therefore, were not in evidence on the trees until a week after the blossoming period, coming suddenly in large numbers. In the spring of 1904, systematic jarring of two trees was begun April 28. One beetle was taken from tree No. 1 on May 4, 1 on May 5, 5 on May 7, and subsequently, a total of 15 by May 19. On tree No. 2 the first beetle was taken on May 17, and 1 the day following. On other trees beetles were taken May 7, and a few subsequently during the month. Apple

buds in 1904 were expending about May 3, trees were in full bloom May 10, and the blossoms had fallen by May 15. As compared with the condition of the trees, in 1904 the beetles were in evidence about two weeks earlier than in 1903.

Some data have been obtained on this point by the Bureau of Entomology. In 1905 records were made by Mr. Johnson, at Youngstown, N. Y., (see Table LIX) and though jarrings were a little late, the results are of interest as showing the occurrence of insects with reference to the condition of the trees.

TABLE LIX.—*Time of appearance of plum curculio on trees in spring. Jarring records, Youngstown, N. Y., 1905.*

Dates trees jarred.	Japan plum.		Domestica plum.		Peach.		Pear.		Condition of trees.
	Trees.	Curculios.	Trees.	Curculios.	Trees.	Curculios.	Trees.	Curculios.	
May 11	50	1	25	2	25	....	....	....	
12	25	9	50	6	25	2	....	....	
15	25	34	....	....	25	2	....	....	Japan and Domestica plums in full bloom.
16	25	1	25	4	25	1	25	....	
17	50	39	50	23	25	1	....	....	Peach in full bloom.
19	25	9	25	12	25	....	25	....	Pears in full bloom.
22	25	8	25	7	25	1	25	2	Plum blossoms fallen.
24	25	6	25	2	25	....	25	1	
27	15	30	15	11	15	4	....	....	
30	25	26	25	15	25	2	....	....	Peach and pear blossoms fallen.
June 1	25	32	....	....	25	2	....	....	
2	....	....	....	....	....	....	....	....	First egg punctures seen on apple and plum.
Total	....	195	....	82	....	15	....	3	

Also, similar data were secured by Mr. Johnson at North East, Pa., in 1906, as shown in Table LX.

TABLE LX.—*Time of appearance of plum curculio on trees in spring. Jarring records, North East, Pa., 1906.*

Dates trees jarred.	Sweet cherry.		Sour cherry.		Apple.		Domestica plum.		Condition of trees.
	Trees.	Curculios.	Trees.	Curculios.	Trees.	Curculios.	Trees.	Curculios.	
Apr. 30	....	....	....	....	25	....	....	....	Cluster buds of apple just opening.
May 2	50	....	50	8	....	....	....	....	
5	25	....	....	....	25	1	....	....	
8	....	....	....	....	50	1	....	....	Sweet cherry and plum trees in full bloom.
14	25	....	....	....	50	6	....	....	
16	25	....	....	....	50	25	25	1	
17	25	....	25	17	....	....	....	....	Sour cherry in full bloom.
20	25	1	25	7	25	25	....	....	
28	....	....	25	7	....	....	....	....	First egg punctures on plums, pears, apples, and cherries seen May 24.
Total	....	1	....	39	....	58	....	1	

The same year (1906) Messrs. Girault and Rosenfeld investigated this point in Georgia. In addition to the trees jarred, as shown in Table LXI, various trees in the woods, as Cratægus, wild plum, etc., were also jarred, but without results.

TABLE LXI.—*Time of appearance of plum curculio on trees in spring. Jarring records, Myrtle, Ga., 1906.*

Dates trees jarred.	Wild plums in thickets.		Peach.		Japan plum.		Pear.		Apple.		Condition of trees.
	Trees.	Curculios.	Trees.	Curculios.	Trees.	Curculios.	Trees.	Curculios.	Trees.	Curculios.	
Feb. 28....	Many.	....	Many.	....	Many.	....	Many.	....	....	......	A few peach and wild plum blossoms open.
Mar. 5....	Many.	....	Many.	....							
9....	Many.	....	Many.	....	....	....	....	....	....	......	Wild plum trees in full bloom.
12....	Many.	....	Many.	....	....	....	....	....	....	......	
14....	Many.	....	Many.	....	Many.	....	....	....	....	......	Pears about in full bloom; Elberta peaches in full bloom.
16....	Many.	....	Many.	....	Many.	....	....	....	....	......	
18....	Many.	....	Many.	....	Many.	....	Many.	....	....	......	
21....	Many.	....	Many.	....	Many.	....	Many.	....	....	......	Blossoms falling from peach, pear, and plum.
23....	Many.	....	Many.	....	Many.	....	Many.		....	......	
24....	Many.	2	Many.	5	Many.	....	Many.	4	....	......	
25....	Many.	....	Many.	....	....	....	Many.	....	....	......	Peaches, pears, and plums well set.
26....	Many.	....	Many.	1	....	....	Many.	....	....	......	
28....	....	....	Many.	3	....	....	....	....	....	......	
29....	Many.	....	Many.	4	....	....	....	....	....	......	
30....	....	....	....	....	Many.	1	....	....	....	......	
Apr. 4....	....	....	....	....	....	....	....	....	A few.	2	Apples in full bloom.
11....	....	....	1,000	227	....	....	....	....	....	......	
13....	....	....	1,000	422	....	....	....	....	....	......	
16....	....	....	1,000	88	....	....	....	....	....	......	
Total...	....	2	....	750	....	1	....	4	....	2	

At Siloam Springs, Ark., in 1908, jarring records were made in a peach orchard as shown in Table LXII.

TABLE LXII.—*Time of appearance of beetles on trees in spring. Jarring records, Siloam Springs, Ark., 1908.*

Dates trees jarred.	Trees.	Curculios.	Condition of trees.
Mar. 18........	950	....	Pears, cultivated plums, and peaches in full bloom; cluster buds on apple showing.
26........	950	....	Petals mostly down from peaches, pears, and cultivated plums.
28........	950	6	
30........	950	....	
31........	950	2	Ben Davis apples nearly in full bloom.
Apr. 2........	950	....	First feeding punctures by caged beetles on peach.
4........	950	1	
6........	950	1	
8........	950	42	Petals mostly down from apples, cherries, and wild plums; calyces beginning to shed from peaches.
11........	950	17	First feeding punctures on peaches in orchard.
13........	950	13	
14........	950	8	First egg punctures in plums.
15........	950	13	
17........	950	64	First egg punctures in peaches.
20........	950	146	
22........	950	169	Calyces entirely shed from peaches.

At Olden, Mo., in the spring of 1907, beetles were out unusually early owing to a protracted warm spell. On March 26, a few feeding punctures were found on Kieffer pear and on newly set cherries. On the same date, egg and feeding punctures were noted on recently set plums. An examination of 200 young plums from an isolated tree gave sound fruit 186, 2 with egg punctures, and 12 with feeding punctures, the fruit being from 3 to 4 mm. in diameter, and the calyces just dropping off. Jarrings made on March 27, of wild plum, cherry, peach, and pear, gave only 3 adults, all from cherry, with fruit barely set. April 4, 30 adults were captured by hand from seedling pear located near peach trees, and about as many beetles escaped. None was found feeding on adjacent apple and peach trees. The condition of the fruit trees at this place is shown by the following: March 24, cherries were in bloom; wild plums well set; petals of Elberta peach and Kieffer pears mostly fallen. March 26, Gano apples were in about one-third full bloom and Ben Davis trees were showing first bloom.

In the vicinity of Washington, D. C., in 1905, a single beetle was taken April 27, and 4 specimens were jarred from peach on the day following. First punctured fruit (plums) was observed May 4, at which time it was about the size of a small bean. Punctures in fruit were increasingly in evidence after this date. Peach and pear trees were in full bloom that year by April 14 and apple trees by April 21. Native and Japanese plums were in full bloom by April 10, and earlier.

On May 2, 1906, a single beetle was captured in the insectary yard, at Washington, on plum. A jarring of 7 peach trees, May 4, gave 14 curculios, and from 8 plum trees 122 beetles were taken. The peaches at this date were just shedding the calyx shucks, and plums were $\frac{3}{8}$ of an inch in diameter. On May 16 curculios were very abundant on peach and plum, a thousand being caught in jarrings from 6 a. m. to 10 a. m. Peach, plum, and pear were in full bloom by April 14 and apple by May 1.

In 1908, pear trees were in full bloom by April 9, while peaches and plums had dropped most of their petals by this date. Apple trees were mostly in full bloom April 24. The first signs of the curculio were noted April 24, when beetles were found feeding upon plum foliage, and additional specimens were found on plums April 27.

Jarring records were made in the spring of 1910 at Barnesville, Ga., North East, Pa., and Douglas, Mich., all in peach orchards. The relation of the appearance of beetles to the condition of the trees at these places is shown in Tables LXIII, LXIV, and LXV.

TABLE LXIII.—*Time of appearance of beetles on trees in spring. Jarring records, Barnesville, Ga., 1910.*

Dates trees jarred.	Trees.	Curculios.	Condition of trees.
Mar. 10	336	19	Scattering blossoms open on Elberta peaches.
14	336	9	Elberta peaches in full bloom.
16	336	1	Red June and Abundance plums in full bloom.
18	336	5	Carmen peaches in full bloom.
21	336	20	
23	336	483	
25	336	840	Petals fallen from Elberta peaches; first egg punctures in plums.
28	336	1,071	
30	336	563	Petals fallen from Carmen peaches.
Apr. 1	336	534	
4	336	427	Peaches bursting through calyces.
6	336	243	
8	336	166	

TABLE LXIV.—*Time of appearance of beetles on trees in spring. Jarring records, North East, Pa., 1910.*

Dates trees jarred.	Trees.	Curculios.	Condition of trees.
Apr. 15	75	3	Less than 5 per cent of peach blossoms open.
20	75	....	About 75 per cent of peach blossoms open.
22	75	....	
26	75	....	Peaches 90 per cent in full bloom.
28	75	....	Peaches shedding some petals.
May 2	75	....	
4	75	....	Nearly all petals fallen from peaches.
6	75	....	All petals fallen from peaches.
9	75	7	
11	75	....	
13	75	1	
16	75	....	
19	75	5	
21	75	19	Peaches beginning to burst calyces.
23	75	22	A few calyces falling.
26	75	22	Many calyces falling.

TABLE LXV.—*Time of appearance of beetles in spring. Jarring records, Douglas, Mich., 1910.*

Dates trees jarred.	Trees.	Curculios.	Condition of trees.
May 4	Many	....	Apr. 25, Elberta peaches, pears, and sweet cherries shedding petals.
7	do	2	
10	do	3	
13	do	2	
16	do	3	Apr. 30, sour cherries in blossom; also apples.
19	do	15	
24	do	115	
26	do	58	May 3, Bartlett pears in blossom; also some peaches.
28	do	67	
June 1	do	57	May 4, Baldwin apples in full bloom.
3	do	74	
6	do	82	May 10, Spitzenberg apples in full bloom.
9	do	97	
12	do	94	
15	do	315	
18	do	350	
21	do	114	
24	do	103	

From the foregoing data it appears that the curculios usually first appear on the trees each season at nearly the same time relative to the advancement of fruit trees, namely, during or a little before the

blooming period of apples or shortly after the petals of peaches, pears, and plums have fallen. In some seasons, however, the curculios may appear as early as the blooming period of the plum or be retarded until after apples have shed the petals. Thus it appears that the beetles are affected by temperature to a different degree than are the plants on which they live. Probably the curculios are more sensitive to short periods of warmth and less so to longer periods at a somewhat lower temperature.

RELATION OF TEMPERATURE TO APPEARANCE OF BEETLES.

A comparison of the numbers of beetles caught in jarrings with the average daily mean temperature immediately preceding each jarring furnishes information on the temperature necessary to bring the beetles out of hibernation. Such data are available from Youngstown, N. Y., for 1905; Siloam Springs, Ark., for 1908; and from Barnesville, Ga., North East, Pa., and Douglas, Mich., for 1910. These are given in Table LXVI.

TABLE LXVI.—*Jarring records showing relation of temperature to appearance of beetles of the plum curculio from hibernation.*

Barnesville, Ga.			Siloam Springs, Ark.			North East, Pa.			Douglas, Mich.			Youngstown, N. Y.		
Dates.	Average of daily mean temperatures since last jarring.	Beetles caught.	Dates.	Average of daily mean temperatures since last jarring.	Beetles caught.	Dates.	Average of daily mean temperatures since last jarring.	Beetles caught.	Dates.	Average of daily mean temperatures since last jarring.	Beetles caught.	Dates.	Average of daily mean temperatures since last jarring.	Beetles caught.
1910.	°*F.*		1908.	°*F.*		1910.	°*F.*		1910.	°*F.*		1905.	°*F.*	
Mar. 10	63	19	Mar. 28	69	6	Apr. 15	43	3	May 7	44	2	May 11	54	3
14	55	9	30	48	....	20	52	....	10	52	3	12	50	17
16	47	1	31	52	2	22	39	....	13	46	2	15	57	36
18	50	5	Apr. 2	61	....	26	45	....	16	45	3	16	59	6
21	57	20	4	43	1	28	45	....	19	54	15	17	59	63
23	59	483	6	52	1	May 2	50	....	24	60	115	19	56	21
25	67	840	8	64	42	4	53	....	26	52	58	22	50	18
28	69	1,071	11	56	17	6	41	....	28	48	67	24	50	9
30	71	563	13	53	13	9	49	7	June 1	51	57	27	59	45
Apr. 1	70	534	14	61	8	11	51	....	3	44	74	30	56	43
4	71	427	15	62	44	13	40	1	6	53	82	June 1	52	34
6	71	243	17	66	64	16	40	....	9	50	97			
8	65	166	20	64	146	19	62	5	12	59	94			
11	62	169	22	66	169	21	60	19	15	63	315			
13	68	95	24	65	75	23	66	22	18	70	350			
15	64	69	27	60	10	26	61	22	21	69	114			
18	64	72	30	46	16	28	50	1	24	75	103			
20	56	12	May 2	51	41	30	60	19	27	72	47			
22	54	53	5	64	13	June 2	46	4	30	68	145			
25	59	15	9	54	28	4	50	13	July 4	74	105			
27	46	16	12	62	57	6	50	6						
29	55	90	14	67	15	8	51	4						
May 2	70	125	21	72	91	10	56	31						
4	73	82	25	71	193	13	57	13						
6	67	52	27	74	198	15	64	19						
9	66	29	30	70	87	16	67	37						
11	65	101				18	66	19						
13	73	31				20	67	28						
						22	70	26						
						25	69	21						
						27	67	19						
						29	68	18						

The effect of temperature in these records is obscured to a considerable extent by other conditions that affect the number of beetles caught by jarring, as winds, rains, proximity to hibernating grounds, and number of beetles previously caught. But the data seem to show that some beetles will become active at a mean temperature of 55 to 60° extending over three or four consecutive days, and that a mean temperature above 60° for several successive days will bring out the beetles en masse. After the beetles have once come out of winter quarters they may be jarred from the trees following periods with a mean temperature much below the degree required to bring them into activity, though such periods of cold weather greatly reduce the numbers caught. In Table LXVII is given a summary of the data in Table LXVI, showing the number of beetles caught at different temperatures for all five localities.

It will be seen from this table that beetles have been jarred in considerable numbers following days with an average mean temperature below 55° and even below 50°. But by a study of Table LXVI it would seem that these beetles had been brought out by earlier spells of warmer weather and were already on the trees when the temperature dropped immediately preceding the jarrings. Probably a mean temperature of between 55 and 60° is required to cause the beetles to leave their hibernating quarters.

TABLE LXVII.—*Number of beetles of the plum curculio jarred at different temperatures, all localities combined.*

Average daily mean temperatures since last jarring.	Jarrings.	Beetles caught.	Average beetles per jarring.	Average daily mean temperatures since last jarring.	Jarrings.	Beetles caught.	Average beetles per jarring.
°F.				°F.			
39	1	....	....	57	3	69	23
40	2	1	½	58	....	....	....
41	1	....	....	59	6	706	118
42	....	....	....	60	4	351	88
43	2	4	2	61	2	22	11
44	2	76	38	62	3	221	73
45	3	3	1	63	2	334	167
46	4	38	9	64	6	361	60
47	1	1	1	65	3	342	114
48	2	68	34	66	5	301	60
49	1	7	7	67	6	991	165
50	9	166	18	68	3	258	86
51	4	102	25	69	4	1,212	303
52	6	98	16	70	5	1,122	224
53	3	95	32	71	4	1,426	356
54	4	99	25	72	2	138	69
55	2	99	49	73	2	113	56
56	5	124	25	74	2	303	151
				75	1	103	103

OCCURRENCE OF BEETLES IN ORCHARDS.

The relative abundance during the season and the distribution of the beetles in orchards are shown to a certain extent by jarring records. Several such records have been obtained, beginning the work of jarring quite early in the spring and continuing at short intervals until the gathering of the fruit crop, or later. The early portions of the following records, with additional ones, have been given in connection with the consideration of activity of beetles in spring.

Table LXVIII gives the results of jarring 950 Elberta peach trees, at Siloam Springs, Ark., for the period from March 28 to June 27, 1908. This block of trees was used to determine the value of jarring in protecting the fruit from injury, as referred to on page 174.

TABLE LXVIII.—*Jarring record for the plum curculio on peach, Siloam Springs, Ark., 1908.*

Dates of jarring.	Beetles caught.	Dates of jarring.	Beetles caught.
Mar. 28	6	May 2	41
30	....	5	13
31	2	9	28
Apr. 2	....	12	57
4	1	14	15
6	1	21	91
8	42	25	193
11	17	26	20
13	13	27	198
14	8	30	87
15	44	June 3	76
17	64	5	112
20	146	11	131
22	169	15	96
24	75	17	107
27	10	19	84
30	16	22	118
		27	128
		Total	2,209

The spring, on the whole, was late, there being much cool and rainy weather. The beetles were notably scarce, only 2,209 insects being captured during the period of jarring, an average of about 2.3 beetles per tree. Considerable variation in the number captured on successive dates of jarring is to be noted. Thus, on May 25, 193 beetles were taken, and the following day only 20. The record indicates the erratic behavior of the beetles due, it is believed, to weather conditions, but shows that by April 8, beetles were out in numbers, the maximum emergence occurring during late May and during June, with a smaller maximum about the third week in April.

In Table LXIX are shown results from jarring a block of 75 peach trees at North East, Pa., during 1910. The trees were in sod and had never received treatment for the curculio. They were jarred every other day, unless weather conditions prevented, beginning April 15 and ceasing September 2. The three specimens captured April 15

indicate a very early movement of the beetles for that locality, though no more were taken until May 9, more than three weeks later. Activity of the insects did not properly begin until May 21, after which date, with the exceptions shown, they proved to be fairly uniform in numbers up to July 2; after the latter date few were captured. A total of 381 individuals was taken during the period, an average of 5 and a small fraction per tree.

TABLE LXIX.—*Jarring record of the plum curculio on peach, North East, Pa., 1910.*

Dates of jarring.	Number of beetles caught.	Weather conditions.	Dates of jarring.	Number of beetles caught.	Weather conditions.
Apr. 15	3	Cloudy.	June 20	28	Clear.
20		Do.	22	26	Do.
22		Fair.	25	21	Do.
26		Cloudy.	27	19	Cloudy.
28		Fair.	29	18	Clear.
May 2		Foggy.	July 2	12	Do.
4		Clear.	5		Do.
6		Do.	7	3	Cloudy.
9	7	Cloudy.	9		Clear.
11		Do.	11	1	Partly cloudy.
13	1	Clear.	13		Do.
16		Do.	16		Clear.
19	5	Do.	19		Do.
21	19	Partly cloudy.	23		Partly cloudy.
23	22	Do.	26		Do.
26	22	Clear.	29		Clear.
28	1	Do.	Aug 2		Do.
30	19	Cloudy.	5		Partly cloudy.
June 2	4		11	2	Clear.
4	13	Fair.	16	2	Do.
6	6	Partly cloudy.	22	2	Foggy.
8	4	Clear.	26	1	Partly cloudy.
10	31	Partly cloudy.	30	1	Do.
13	13	Do.	Sept. 2		Do.
15	19	Clear.			
16	37	Partly cloudy.	Total	381	
18	19	Clear.			

In the jarring records obtained during 1910, at Douglas, Mich., a block of 70 peach trees was used, and the number taken on each row at each jarring was separately recorded. Row No. 1 was adjacent and parallel to a piece of woodland, the influence of which is evident by the larger number of insects taken early in the season from the first two or three rows. After about June 9 the beetles were uniformly disseminated over the whole block. From May 4 to 10, a total of 5 beetles was secured and from May 13 to 19, a total of 20. From the last date they put in an appearance rapidly, showing for the period from May 24 to 28 a total of 240. The beetles were in maximum abundance during June, which month yielded 1,468, or 59 per cent of the total for the season. The insects, nevertheless, were quite generally present all through July and August. None was taken after August 31, though jarrings continued until September 19. (See Table LXX.)

TABLE LXX.—*Jarring record for the plum curculio on peach, Douglas, Mich., 1910.*

Dates of jarring.	Curculios caught by rows.						Total.
	Row 1.	Row 2.	Row 3.	Row 4.	Row 5.	Row 6.	
May 4							
7		1	1				2
10		1	1	1			3
13	1					1	2
16	1				2		3
19	5	6	1		3		15
24	33	39	19	8	4	12	115
26	19	22	7	6	2	2	58
28	21	26	8	4	5	3	67
June 1	12	21	9	1	1	3	47
3	25	20	16	5	2	6	74
6	22	18	11	5	19	7	82
9	31	25	8	11	11	11	97
12	18	20	16	15	12	13	94
15	84	87	37	31	51	25	315
18	67	85	87	51	40	20	350
21	22	27	19	18	15	13	114
24	19	21	25	23	9	6	103
27	10	11	11	3	10	2	47
30	12	41	25	26	27	14	145
July 4	9	27	36	10	13	10	105
7	8	14	6		2	2	32
9	7	5	4	1		2	19
12	13	19	17	7	6	11	73
15	3	5	23	13	33	14	91
18	5	8	8	6	18		45
21	2	9	9	12	8		40
25	3	9	7	8	3	3	33
27	1	9	5	6	7	1	29
30	2	6	1	1	4		14
Aug. 4	3	4		5		1	13
7	1	2	3	2		4	12
10	6	8	16	3	6	7	46
13	6	5	8	10	9	7	45
17	8	3	11	8	9	3	42
20	1	2	11	8	12	6	40
24	3	14	14	7	9	6	53
27	3	1		3	4	2	13
31	6	3	2		4	5	20

By far the most complete record, however, was obtained at Barnesville, Ga., during 1910 (see Table LXXI). This work was accomplished by Mr. E. W. Scott, though completed during the latter part

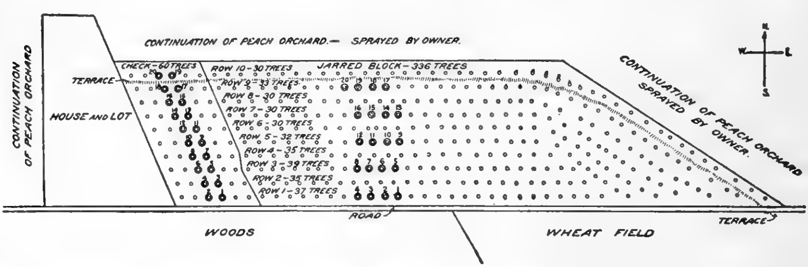


FIG. 24.—Diagram of portion of peach orchard used in jarring experiments against the plum curculio, Barnesville, Ga., 1910. (Original.)

of the season by the junior author. Ten rows of Elberta peach trees were used, paralleling a piece of woods. Row No. 1 was separated from woods by only a wagon road. A total of 336 trees was jarred, all as indicated in the diagram (fig. 24). As shown in the figure, a terrace covered with grass and weeds bordered all of the rows on the

east, and extended between rows Nos. 9 and 10. Excepting a check of 60 trees extending across the 10 rows on the west end, the trees surrounding the jarred block to the east and north were sprayed by the owner with arsenate of lead in self-boiled lime-sulphur wash.

TABLE LXXI.—*Jarring record for the plum curculio on peach, Barnesville, Ga., 1910.*

Dates of jarring.	Number of curculios caught, by rows.										Total.
	Row 1.	Row 2.	Row 3.	Row 4.	Row 5.	Row 6.	Row 7.	Row 8.	Row 9.	Row 10.	
Mar. 10	16	....	2	....	....	....	....	1	....	....	19
14	5	1	....	....	1	....	....	....	1	1	9
16	....	1	....	....	....	....	....	....	....	....	1
18	3	1	....	....	....	....	....	....	....	1	5
21	15	1	1	1	....	1	....	....	....	1	20
23	406	27	10	6	....	6	7	1	5	15	483
25	460	140	56	45	32	13	14	15	16	49	840
28	550	125	95	58	38	33	30	33	35	74	1,071
30	206	77	57	36	21	24	29	21	38	54	563
Apr. 1	186	74	54	33	18	19	23	18	54	55	534
4	92	38	45	39	32	29	37	21	45	49	427
6	93	36	38	17	10	3	2	6	10	28	243
8	71	23	21	5	3	4	3	6	9	21	166
11	54	30	16	6	9	10	13	7	7	17	169
13	34	13	14	4	3	2	5	3	6	11	95
15	31	8	8	3	....	3	3	1	3	9	69
18	22	10	8	4	3	3	5	2	5	10	72
20	5	2	....	1	....	....	....	....	....	4	12
22	9	11	5	5	2	2	1	3	7	8	53
25	5	....	1	3	1	....	....	1	2	2	15
27	3	4	1	1	....	3	2	....	1	1	16
29	23	8	9	4	2	2	2	4	10	26	90
May 2	41	21	13	3	7	3	7	6	10	14	125
4	33	5	5	4	4	2	6	2	6	15	82
6	12	3	5	1	3	3	....	2	10	13	52
9	7	5	1	2	....	1	....	....	8	5	29
11	39	14	3	6	4	2	8	8	9	8	101
13	13	3	1	....	1	1	1	....	5	6	31
16	4	1	3	....	1	....	1	....	....	....	10
18	6	1	....	2	....	....	2	1	2	4	18
20	37	11	9	5	2	4	6	4	9	11	98
23	23	6	6	3	3	1	2	1	4	12	61
25	18	2	3	4	3	....	1	2	4	4	41
27	15	10	3	3	2	3	1	2	4	6	49
30	17	10	2	4	3	2	3	2	8	7	58
June 1	4	1	....	2	2	1	....	....	2	3	15
4	10	1	1	1	....	2	3	....	6	5	29
7	81	46	14	7	8	7	8	8	16	36	231
9	55	14	17	16	6	3	12	11	30	31	189
11	21	11	6	7	2	4	2	3	3	4	63
14	44	17	8	2	5	6	5	8	15	17	127
16	36	25	13	7	4	4	3	4	16	19	131
18	35	21	9	8	4	7	6	5	21	6	122
20	15	6	7	2	2	1	4	1	8	8	54
22	8	2	3	1	2	2	....	....	8	8	34
24	16	7	2	4	2	3	2	2	8	3	49
27	16	5	5	4	2	3	3	3	2	8	51
29	6	7	3	1	3	....	....	1	....	8	29
July 2	4	3	2	1	1	....	2	1	2	1	17
5	13	3	2	2	....	1	....	1	....	2	24
8	6	4	....	....	....	1	....	1	....	4	16
11	4	3	1	4	2	....	3	1	....	5	23
25	13	5	3	3	2	....	....	1	3	4	34
29	12	6	5	3	....	....	....	....	2	1	29
Aug. 2	10	2	1	1	1	....	....	1	5	3	24
5	1	3	2	....	....	....	....	....	....	2	8
8	5	2	2	....	....	....	....	....	....	1	10
12	1	1	1	1	1	....	....	....	1	....	6
15	5	2	....	1	....	....	....	....	....	2	10
19	3	2	1	....	....	....	....	....	....	1	7
22	13	4	5	....	....	1	....	....	3	2	28
26	6	3	5	....	....	....	....	....	6	6	26
29	2	3	....	....	....	....	....	....	1	1	7
Sept. 2	65	10	4	8	1	1	3	....	2	25	119
5	36	13	8	3	1	2	2	....	5	8	78
10	7	1	3	....	1	....	2	....	....	4	18
12	32	3	4	....	4	1	1	1	2	9	57
16	14	4	2	....	1	....	....	1	....	2	24

TABLE LXXI.—*Jarring record for the plum curculio on peach, Barnesville, Ga., 1910*—Continued.

Dates of jarring.	Number of curculios caught, by rows.										Total.
	Row 1.	Row 2.	Row 3.	Row 4.	Row 5.	Row 6.	Row 7.	Row 8.	Row 9.	Row 10.	
Sept. 23	16	5	4	1	2	....	....	....	1	3	32
27	3	3	1	....	....	....	....	....	....	2	9
30	8	....	1	1	....	....	....	....	....	1	11
Oct. 4	1	2	....	....	....	....	....	....	1	....	4
7	3	1	....	....	....	....	....	....	....	1	5
11	13	2	1	....	2	....	....	....	1	2	21
15	....	....	....	....	....	....	....	....	....	....	....
18	....	....	....	....	....	....	....	....	....	....	....
22	....	....	....	....	....	....	....	....	....	....	....
Total.	3,197	975	641	393	269	229	275	227	503	788	7,497

A study of this table shows the beetles to have first become active March 10, when 16 were taken on row No. 1. During the interim March 18 to 23 they began to appear in numbers, and were out in full force during the last week of March. Considering the results of jarrings from the individual rows, the influence of the woods as hibernation quarters is very plainly shown. Thus, up to March 23 rows Nos. 1 and 2 gave a total of 476 beetles, as against 61 from the other eight rows. By March 25, 15 days after emergence began, diffusion of the beetles had become quite general over the block, though the number taken from the first row on a given date was in most cases in excess of that taken from any other single row. For the season, row No. 1 yielded 3,197 beetles, 42.64 per cent of the whole number captured. From the first three rows adjacent to the woods a total of 4,813 individuals was taken during the season, or 64.19 per cent of the total. The influence of the grass-covered terrace between rows Nos. 9 and 10 is also evident, more insects being captured from each of these than from any one of the rows Nos. 4 to 8. The beetles were in maximum abundance in the orchard from about March 25 to April 13, during which period 4,108 individuals were taken, or 54.79 per cent of the total.

The appearance of the new generation of beetles is marked by a sudden increase in the jarrings for June 7 and several days subsequently. Beginning with the third week in August an increase in the number of beetles taken is again noted, reaching its maximum about September 2. This may doubtless be attributed to the issuing of the beetles that developed from ripening fruit, the ripening period being approximately July 7–20.

No beetles were captured in this orchard after October 11, though the jarrings were continued to October 26. But during late fall jarrings were made in other orchards, both sprayed and unsprayed, and also in woods adjoining peach orchards. After beetles ceased to appear on the regular jarred plats, many were taken in some of these

other places. On October 12, 3 beetles were jarred from 60 trees in a sprayed orchard, and 1 beetle from 50 oak and hickory trees in adjoining woods. On October 14, 133 beetles were jarred from 104 trees in a badly infested unsprayed orchard consisting of late varieties. The trees in this orchard had been bare of foliage for more than two weeks. On the same morning 144 beetles were jarred from 28 small oak trees in woods adjoining this orchard, showing a heavy migration to the woods. The same 104 peach trees were again jarred October 23. Only 30 beetles were taken, and only 7 beetles from 20 oak trees in the adjoining woods. On October 26 as many trees as possible were jarred in the woods adjacent to the regular jarred block of peach trees. Only 3 beetles were secured The last beetles of the season were jarred November 1, when 2 beetles were taken from the 104 trees in the unsprayed orchard previously mentioned. No beetles were secured in jarring 18 oak trees in the adjoining woods on the same date. This probably marks the complete entrance of the insect into hibernation.

NUMBER OF GENERATIONS ANNUALLY.

It has been accepted for years that there is but one generation of the curculio annually, though this was a much-disputed question among the earlier writers. Thus, the writer of an article in the National Gazette, which was reprinted in the American Farmer of November 15, 1830, states: "There are three generations of them during the five months of their existence above ground, and they are all very tenacious of life." Dr. Fitch [1] believed the insect to be two-brooded each year, the second brood passing the winter in the larval condition under the bark of pear trees. He was led to this erroneous belief by the resemblance to the curculio crescent of a curved incision in the bark which he supposed was the egg puncture of the insect in question. The absence of fruit he thought necessitated this change in egg laying by this brood, and agreed with the earlier observations of Melsheimer that the curculio bred in the bark of peach trees. Dr. Trimble, as the result of observations, believed the curculio to be single-brooded, and this opinion was, in the main, accepted by subsequent writers. Dr. Riley, however, in an anonymous communication under the signature of "V" in the Prairie Farmer for July, 1867, gave it as his conclusions that the insect was occasionally two-brooded. In his first Illinois report (1867), Walsh states his belief in the double-broodedness of the curculio, as follows: "I find there are two distinct broods of the plum curculio every year, the first of which comes out in the beetle state, in the latitude of Rock Island, Ill., from about July 19 to August 4, and the second from about August 23 to Septem-

[1] 3d Rept. Ins. N. Y., p. 351.

ber 28." He cites in detail rearing experiments to support his conclusion, and cites Riley's note in corroboration.

Riley [1] fully corroborates the conclusions of Dr. Trimble by rearing the curculio in a large cage over a tree, and states emphatically that the curculio is single-brooded, but further goes on to say:

> But as there seem to be exceptions to all rules, so there are to this; yet the exceptions are only just about sufficient to prove the rule, for as far south as St. Louis not more than 1 per cent of the beetles lay any eggs at all until they have lived through one winter; or, in other words, where one female will pair and deposit a few eggs the same summer she was bred, ninety-nine will live on for nearly 10 months and not deposit till the following spring. In more northern latitudes I doubt if any exception to the rule will be found.

During the present study of the curculio but little information on the tendency of the insect to produce a second brood under field conditions has been secured. Late records of larvæ in fruit could readily be accounted for as from eggs deposited by the longest-lived individuals of the overwintering beetles.

During 1905, however, at Washington, D. C., a second brood of larvæ was obtained, though no individuals reached the adult condition. Infested peaches were received May 1 from Fort Valley, Ga., and confined over moist soil in a large covered glass jar kept in the insectary, where temperature conditions were abnormally high. By June 8 many adults were emerging from the soil, and on June 12 several apples were added. On July 13 eggs were found in four apples, and subsequently fertile eggs were laid on the 17th, 20th, 21st, 22d, and 24th of July, and by August 2 several larvæ had developed to full size, some remaining in the fruit and others entering the soil. Several larvæ were separated for particular observation, but all of these died without transforming to the pupal stage, and no adults were secured from larvæ entering soil in the breeding jar.

During the summer of 1910 a second generation was again reared under laboratory conditions, at Barnesville, Ga., this time a large number of individuals being reared to the adult stage. Adults of the first generation were reared out of doors from infested peaches gathered in an orchard, the beetles beginning to emerge June 6. On emerging, the beetles were put in large muslin-covered battery jars, 100 to 175 beetles to each jar, and kept in the laboratory. They were fed on peach foliage and fruit, but were often neglected, allowing the jars to become very humid and sometimes moldy. On July 11 several eggs were found in peaches taken from these jars. The beetles, 480 in number, were then supplied with ripe Elberta peaches from which all curculio eggs had been removed. On examining this fruit two days later 113 eggs were found. Eggs were subsequently obtained in abundance, a typical record of eggs laid in fruit left in the jars overnight being shown in Table LXXII.

[1] Third Missouri Rept., p. 11.

TABLE LXXII.—*Record of eggs laid by 864 new-generation beetles during one night, Barnesville, Ga., 1910.*

Dates of observation.	Beetles in jars.	Dates beetles emerged from soil.	Eggs laid.
Night of July 26	120	June 17	6
Do	113	June 18–19	11
Do	156	June 20–22	16
Do	185	June 23–25	49
Do	109	June 26–29	20
Do	101	June 30–July 4	27
Do	80	July 5–16	13
Total	864		142

The beetles continued to oviposit freely until August 10. By this time peaches were scarce and no further observations were made until August 17, the beetles being fed on foliage alone during the intervening week. On August 17 some late seedling peaches, both green and ripe, were put in the jars and on the next day were examined for eggs, only two being found. No more eggs could be obtained from these beetles or from beetles recently captured by jarring, although eggs were being laid in the field, where fruit was available, for a month longer.

All eggs laid by the new-generation beetles appeared to be fertile and hatched in from three and one-half to four and one-half days unless injured by handling. One hundred and eighty-five individuals were reared through to the adult state under the same outdoor conditions used in the other rearings. The larvæ developed in ripe peaches, remaining in the fruit from 9 to 24 days. The life in the soil ranged from 18 to 45 days and the entire life cycle from 36 to 61 days. The adults from this material emerged from the soil August 22 to October 10. Adults from infested peaches collected in the field emerged as late as November 9, at which date there were yet many pupæ and even larvæ in the soil, though there is no evidence that these late individuals from the field were of the second generation.

BEETLES FROM EMERGENCE TO HIBERNATION.

In general, after emergence the adult insects pass the time in hiding and feeding, their activities growing less and less at the approach of cold weather, until finally they seek hibernation quarters for the winter, which, as shown, may be in orchards under trash, etc., on the ground, but especially in neighboring woods.

More detailed information is needed upon the habits of the beetles after emergence, especially in the South and in other regions where the fruit crops are practically all gathered by midsummer or earlier. Under such conditions the weevils are at once largely deprived of fruit for food and doubtless subsist on foliage, buds, etc. In regions, as the Middle and Northern States, where a variety of later maturing

fruits is grown, as apples, pears, late peaches, plums, etc., this exigency in the life of the insect does not occur. Nevertheless, the weevil in the Southern States is able to maintain itself in extended areas largely devoted to peach growing, as shown by the fact that the insect is here perhaps most abundant and destructive.

The jarring records presented on page 120 show the beetles to be present in peach orchards until quite late in the season, but not in such numbers as during spring and early summer, indicating a considerable diffusion or early seeking of hibernation quarters. During September, 1905, Mr. Beattie, at Fort Valley, Ga., jarred 400 peach trees, securing 600 beetles, which he states were very active and were captured on the sheets with difficulty.

Beetles kept in confinement from time of emergence until hibernation have fed freely on fruit when present or on foliage when supplied with this alone. Their forced feeding on foliage, as in the South, suggests the possibility of destroying them in large numbers by thorough spraying with arsenicals after the fruit has been harvested, insuring their material reduction another season.

In the more northern States the beetles feed freely on various fruits but are especially destructive to the apple. The so-called fall feeding puncture, in fact, constitutes an important injury to apples, pears, plums, etc. The puncture differs somewhat from that made in the spring by the overwintering generation. The cavity is cylindrical, as in the case of the spring puncture, but somewhat deeper, and is usually excavated beneath the skin all around, as far as the length of the snout of the beetle will permit. The opening through the skin, about one-sixteenth of an inch in diameter, is surrounded with a darkened circle, due to the cavity beneath, which, if the skin be removed, will be found to be from one-eighth to one-fourth inch across. A single cavity is rarely more than one-eighth inch deep, but where the insects are numerous and the fruit scarce the feeding punctures may be so abundant as to run together, with the result that the injured area of the apple, due to the evaporation through the broken skin, collapses, quite destroying the fruit for market purposes. (See Pl. XIII.) Wasps and other agencies, following the curculio, may further excavate these feeding punctures, which may be invaded by rot-producing fungi and bacteria, soon bringing about the decay of the fruit. Often the punctures become so enlarged that the beetles are able to get inside, where they feed and rest, perhaps spending days there at a time. This character of injury was noted years ago by Prof. Comstock.[1]

The extent to which the beetles feed in the late summer was determined by Crandall for 10 individuals, separately confined, and furnished fresh food, 5 of them daily, the balance about once each

---

[1] Bul. 3, Cornell Univ. Agr. Exp. Sta., p. 40 (1888).

FIG. 1.—CHARACTERISTIC HOLES EATEN INTO APPLE BY THE BEETLES IN THE FALL. (ORIGINAL.)

FIG. 2.—FEEDING PUNCTURES OF BEETLES ON SUMMER APPLES. (ORIGINAL.)

THE FALL FEEDING PUNCTURE OF THE PLUM CURCULIO ON APPLE.

week. A total of 529 punctures was made, or an average of 52.9 per individual, the range being from 8 to 111 punctures. Examinations as to curculio injury during the fall of many thousands of fruits, as apples, European plums, pears, etc., have always shown the feeding punctures of the new generation of beetles, and unquestionably the latter feed freely after emergence and until hibernation.

HIBERNATION.

The curculio passes the winter in the adult or beetle stage in trash in and about orchards, along fences, and in adjacent woods, etc. This fact in the life of the insect has been fairly well understood for many years.

Dr. Tilton, in his article in Willich's Domestic Encyclopedia, in 1804, expressed the belief that the curculio, like other beetles, remains in the form of a grub (or worm) during the winter, ready to be metamorphosed to a bug (or beetle) as the spring advanced.

Dr. Harris,[1] in describing the life history of the insect, as a result of his observations, says:

> Meanwhile the grub comes to its growth, and immediately after the fruit falls burows into the ground. This may occur at various times between the middle of June and of August, and in the space of a little more than three weeks afterwards the insect completes its transformations and comes out of the ground in the beetle form.

He further adds that he has not yet been able to confirm Dr. Tilton's observations, but believes that some grubs may be retarded in their transformations, thus passing the winter.

Dr. Fitch [2] states:

> Notwithstanding the volumes that have been written upon it, we do not to this day know where the curculio lives and what it is doing three-quarters of the year.

Dr. Trimble (loc. cit., p. 99) writes:

> Many believe that the curculio lives through the winter in the immature condition of a grub and undergoes its transformations in the spring. This is not so. In all my numerous experiments made year after year, even with the latest-stung apples, the grubs become beetles the same season, and as beetles they live somewhere through the winter.

Further, he details the keeping of beetles in flowerpots covered with cheesecloth until quite torpid from the cool weather. Specimens of beetles were found by Dr. Trimble hibernating under the shingles of a roof and in the crevices of a stone wall.

As stated by Walsh, specimens of beetles were found by a Mr. Rathvon under bark of cherry and wild cherry in March and November. Walsh [3] states:

> There is little doubt now in my mind that the curculios bred from the fruit of one year are the same individuals that puncture the fruit of the following year.

[1] Nat. Hist. Mass., p. 67 (1841).
[2] Two Addresses, Insects and Curculio (1860).
[3] Practical Entomologist, p. 77 (1867).

But later he complicates the subject by his conclusion that the curculio is double-brooded, and that it is the beetles of this second brood that survive the winter. On this point of hibernation Riley,[1] in a summary statement concerning the knowledge of the insect at that time, states—

That the greater portion of them pass the winter in the perfect beetle stage under the old bark of both forest and shade trees, under shingles and logs, rubbish of all kinds, and especially the underbrush of the woods.

That a certain proportion of them also pass the winter underground, both in the larval and pupal stages, at a depth frequently of from 2 to 3 feet.

That those which hibernate as beetles begin to leave their winter quarters and enter our orchards throughout central Missouri during the first days of May, and commence to puncture the fruit about the middle of the same month—a little earlier or later, according to the season—the fruit of the peach being at the time about the size of a small marble.

However, Riley, in his Third Report (p. 13), expresses a different opinion, and says that he has satisfied himself that the curculio invariably passes the winter as a beetle under shelter of all sorts near the surface of the ground. This conclusion seems to have been adopted by nearly all subsequent writers. There has been, however, little exact information on the places where the curculio hibernates, and indeed little direct effort has been made to find them in hibernation.

Prof. Crandall (loc. cit., p. 495) reports results of searches for beetles in Illinois in the spring of 1903. On March 31 a whole day's search revealed none. Search was made again on April 14, and at intervals up to April 27, when first beetles were found under dead grass on the ground and occurring singly. Examinations of the trees in spring did not reveal the beetles until May 10, when they appeared to come all at once, none having been found on the day previous. Further search of hibernation quarters, in 1904, was made by Prof. Crandall, but no beetles could be found.

The hibernation habits of the curculio have been investigated at various times during the course of the present study of the insect. At Youngstown, N. Y., in 1905, Mr. Johnson made frequent searches in the fall during October, and on the 14th of that month 9 beetles were discovered in a slight depression under an apple tree. They were well covered with closely matted, well-decayed leaves within a space about 2 inches square. Nine more beetles were found in a similar situation in an apple orchard on the 16th. On October 25 an examination of an uncultivated orchard in light soil revealed none, but in an adjoining orchard where there was a sparse covering of sod and leaves on the ground, 6 beetles were taken, 4 being quite dormant and 2 capable of moving feebly. A search on November 4 among leaves on the ground in an apple orchard failed

[1] First Missouri Report, p. 53 (1869).

to reveal any beetles, but, on November 7, 6 more specimens were taken beneath partly rotted leaves close to the soil. The beetles were wet and dull colored from their surroundings. On November 17, 2 adults were found, under rotted apple leaves on soil, quite active; and in a similar situation 4 more were taken November 23, and 5 on November 28. In the spring of 1905 Mr. Johnson made extended searches for beetles along fence rows, in peach, plum, apple, and quince orchards, in old stumps in adjoining woods, in cracks in fences, under piles of wood, rough bark of fruit and other trees, and wherever it was thought possible that the beetles might occur. None, however, was discovered. Examinations were made beginning March 25 and continued until May 10, at which time plum trees were showing first blossoms.

The following year, 1906, at North East, Pa., Mr. Johnson found, on April 24, 10 beetles covered with leaves and decayed fruit on the surface of the ground in a young apple orchard in sod. At this time the blossom buds of apple were just beginning to open. Beetles were found in similar situations in this orchard, as follows: Seven on April 25, 9 on April 26, 4 on April 30, 16 on May 3. By this time, however, beetles were in evidence on certain fruits, as shown by Table LXIX, and it is not certain but that some of the beetles observed had already left their hibernation quarters for the orchards.

Also, in the spring of 1905, Mr. James H. Beattie, at Fort Valley, Ga., made frequent searches for hibernating curculios, the work covering the period from March 14 to 25. Examinations were made among leaves and logs in woods, trash in orchards, and other places where the insect might occur, but none was found, though unquestionably they were quite abundant in these places.

The following year at Myrtle, Ga., Messrs. Girault and Rosenfeld failed utterly to find any hibernating curculios, although very careful search was made in all situations likely to be used, including trash and grass along terraces, in peach orchards, in thickets of wild plum trees adjacent to peach orchards, in accumulations of leaves and trash, in old stumps, under rough bark of trees, etc. One beetle, however, was found March 16 under the bark of a pear tree about 4 feet from the ground under circumstances suggesting that it had hibernated there. There is doubt in regard to the matter, since the trees at this time were in full bloom and the insect may have come into the orchard from its hibernating quarters.

In the case of apple orchards the data show that many beetles simply hide away under trash that may be present. They doubtless feed upon the fruit until fall, and upon the coming of cold weather seek the most convenient shelter. In the case of fruits gathered by midsummer, as is true of peaches in the South and in regions where other fruits are not available for food, unquestionably the insects

become very much scattered, and there are no data to show just where they hibernate, though it has long been known that beetles are first in evidence in those portions of orchards adjacent to woods. (See tables of jarring records, pp. 120–125.) Unquestionably the bulk of them hibernate in trash in woods adjacent to orchards, and also in grass along terraces in orchards, and probably to a less extent in orchards.

Some data were obtained also by Mr. Johnson at Youngstown, N. Y., in the fall of 1905, upon the actions of the beetles in seeking protection. On September 28, 6 curculios were placed on bare loose soil and covered with large glass jars. After several days of cold weather, including a couple of hard freezes, the beetles were found on October 20 on the surface of the soil and in a perfectly quiescent condition. Later, November 13, there had been no change in the condition of the beetles. Specimens collected early in September, feeding upon apples and confined in jars, in which was a supply of turf, made no attempt to burrow into the sod. As the weather became colder they mostly fell from the apples, inclosed for food, lying promiscuously among the blades of grass at the base of the fruit. Beetles were still hiding in cavities previously eaten in the apples. On November 22, however, after some activity, due to a few days of warm weather, several beetles had crawled nearly out of sight in the sod and several more had worked down into cracks between the pieces of sod, indicating a distinct tendency to seek shelter.

MORTALITY OF THE CURCULIO DURING HIBERNATION.

The proportion of beetles which survive the winter doubtless varies considerably from year to year, depending upon the character of the weather and other conditions. Observations on this point, however, indicate a heavy mortality. September 4, 1905, 400 beetles jarred from peach trees at Fort Valley, Ga., were placed in breeding cages in the insectary yard at Washington and supplied with fruit for feeding purposes and abundant dried leaves and trash under which to protect themselves during the winter. Examinations made October 12 and 28 indicate that they were doing well and had fed more or less upon the fruit present. At these dates most of the beetles were hiding under the trash at the bottom of the cage. A preliminary examination, March 2, 1906, showed that many of the beetles had become active, some of them crawling rapidly here and there in the cage. On April 6 a final examination was made, especial care being taken to miss none of the insects. The leaves and sand were carefully worked over, and 60 live beetles were found and 138 dead ones. Thus a total of 198 individuals were accounted for out of 400 originally placed in the cage. Doubtless the missing ones had

died and decomposed and thus escaped notice. Their escape from the cage was scarcely possible, as this was kept tightly closed all the while. A similar experiment was made at Siloam Springs, Ark., in the fall of 1908. October 9, 1,280 beetles reared from peaches were distributed in four battery jars and kept out of doors under shelter. An examination on November 2 showed that 965 beetles were alive and 308 dead, with 7 unaccounted for. These 965 beetles were then placed in a cage in a moderately exposed place out of doors and covered to protect from beating rains. The cages were supplied with a quantity of small chips, dried leaves, paper, and muslin. The insects passed the winter in this condition, but unfortunately the cage met with an accident in the spring and final results were not obtained. In the course of rearing work at Barnesville, Ga., during 1910 many beetles were obtained, some of which were used to obtain data on their mortality before hibernation in the fall and during the winter. As shown in Table LXXIII, 10 different lots of beetles were thus carried through the fall and winter in boxes covered with wire screen, the total number of individuals under observation being 2,378. Up to November 4, 1910, the time of final examination in the fall, a total of 487 beetles had died, with 112 unaccounted for and listed as escaped. A total of 1,779 beetles were placed in cages as shown for the winter. At date of final examination in the spring, March 8, 1911, 648 live beetles were found, with 619 dead and 512 missing; the last probably decomposed. The average percentage alive is seen to be 36.42. The percentage of mortality of the different lots does not seem to give consistent evidence as to hibernation material and exposure best suited to them, as will be noted from the table:

TABLE LXXIII.—*Mortality of hibernating beetles of the plum curculio, Barnesville, Ga., 1910–11.*

Lot No.	Period of emergence.	Emerged.	Food.	Lost while feeding up to Nov. 4, 1910.		Total put in winter cage.
				Died.	Escaped.	
	1910.					
1	Sept. 16–30	138	Peach foliage and apples	4		134
2	June 13–22	573	Peach foliage, peaches, and apples.	294	57	222
3	Oct. 1–Nov. 3	101		2		99
4	Aug. 6–Sept. 6	311	Peach foliage only	72	9	230
5	June 30–July 16	181	Peach foliage, peaches, and apples.	38	18	125
6	Sept. 7–9	216	Peach foliage only	6	4	206
7	June 23–29	294	Peach foliage, peaches, and apples.	38	9	247
8	Sept. 10–15	127	Peach foliage and apples	6	2	119
9	Oct. 11–22 [1]	[1] 317	do	14	1	302
10	June 17	120	Peach foliage only after Aug. 30.	13	12	95
Total.		2,378		487	112	1,779

[1] Jarred.

TABLE LXXIII.—*Mortality of hibernating beetles of the plum curculio, Barnesville, Ga., 1910–11*—Continued.

Lot No.	Date put in winter cage.	Hibernation material used and exposure.	Date final examination.	Alive.	Dead.	Missing.	Percentage alive.
	1910.		1911.				
1	Nov. 4	Chips; exposed to rain	Mar. 8	79	16	39	58.95
2	...do....	Sod; exposed to rain	...do....	104	60	58	46.84
3	...do....	Dry leaves; exposed to rain	...do....	64	24	11	64.64
4	...do....	Dry leaves; sheltered	...do....	53	133	44	23.04
5	...do....	Hay; exposed to rain	...do....	113	3	9	90.40
6	...do....	Dry leaves; exposed to rain	...do....	111	59	36	53.88
7	...do....	Bare dirt; exposed to rain	...do....	86	94	67	34.81
8	...do....	Chips; sheltered	...do....	1	100	18	.84
9	...do....	Dry leaves; exposed to rain	...do....	2	127	173	.66
10	...do....	Dry oak leaves; exposed to rain	...do....	35	3	57	36.84
Total				648	619	512	[1] 36.42

[1] Based on totals.

Observations on the hibernation of beetles were also made by Mr. Hammar during 1910 at Douglas, Mich. To determine if any individuals lived over two seasons, a lot of beetles, 1,591 in number, were placed in rearing jars as collected from the trees between May 7 and June 30, and before any beetles of the new generation had appeared. These were supplied with food during the summer and fall until hibernation. On May 10, 1911, the contents of the cages were examined and the sand sifted, and 1,400 individuals recovered. No live beetles, however, were found, though some were alive in the fall. This indicates that the beetles do not live over a second winter.

A lot of beetles, 610, reared from fruit in the laboratory during the summer of 1910 was placed in a rearing cage in a protected place out of doors and fed until hibernation. At the final examination, May 10, 1911, 416 dead beetles were found and the remains of a few disintegrated individuals. The live beetles unfortunately had escaped through an imperfection which developed over winter in the cage. These figures, however, give a winter mortality of about 70 per cent.

PERCENTAGE OF FRUIT PUNCTURED OR INFESTED BY THE PLUM CURCULIO.

In a general way it has long been known that the curculio, throughout its area of distribution, injures or destroys a large amount of fruit each year. The amount of injury will vary from season to season, and will depend more particularly upon local conditions in the orchard. Injury will be notably worse in uncultivated orchards and where good hibernation quarters are afforded the beetles. Cultivated and sprayed orchards suffer least, though in well-cultivated, southern peach orchards the pest is often quite destructive. In connection with spraying experiments during the past several years, the percentage of fruit injured by the curculio on untreated trees has been

determined for various fruits and localities by actual counts of fruit. Typical data of this kind are furnished in the tables following. Not all fruit punctured is worthless, though its market value is reduced.

In Table LXXIV are given data on amount of fruit infested by larvæ from specified trees in several localities in Georgia and in Pennsylvania, including both drop and picked fruit. On account of the difficulty of determining punctures in the peach, only actual infestation was noted, mostly of fallen fruit.

TABLE LXXIV.—*Percentage of infested peaches for the season, various localities.*

Localities.	Season.	Variety.	Trees used.	Fruit from ground.			Fruit from trees.			Total infested.	Total sound.	Percentage infested for season.
				Infested.	Sound.	Total.	Infested.	Sound.	Total.			
Mayfield, Ga.	1907	Elberta	5	328	229	557	518	113	631	846	342	71.21
Marshallville, Ga.	1908	Red River	4	167	467	634	100	2,264	2,364	267	2,731	8.91
Myrtle, Ga.	1906	Belle of Georgia	12	231	238	469	264	895	1,159	495	1,133	30.40
Arlington, Va.	1906	Miscellaneous	5	593	1,495	2,088	35	489	524	628	1,984	24.04
North East, Pa.	1906	Sneed	8	2,522	941	3,463	0	2,200	2,200	2,522	3,141	44.53
Do.	1906	Hills Chili	4	831	171	1,002	0	848	848	831	1,019	44.91
Total and average per cent of injury				4,672	3,541	8,213	917	6,809	7,726	5,589	10,350	35.06

As shown in Table LXXIV, the percentage of infestation to peaches in the several localities varies from 8.91 to 71.21 per cent of the total crop produced, with an average of 35.06. These figures represent the actual proportion of the crop destroyed, since it includes only infested fruit. The total number of infested fruits from the ground, 4,672, exceeds notably that infested on the trees, i. e., 917. The percentage of drop fruit infested is 56.87, as compared with 11.86 per cent from the trees at picking time. During seasons of light crops practically all of the fruit may become infested when small and drop, though during years of full crops the thinning out by the beetles is not especially important.

In Table LXXV is shown the condition of the drop fruit for the season from 120 Elberta peach trees at Siloam Springs, Ark., during 1908. The fruit at picking time was by mistake of orchardist

removed before records could be made of condition of same. The percentage of infestation, 11.25, is notably less for drop fruit than shown in the preceding table, 56.87, due to the greater scarcity of the beetles.

TABLE LXXV.—*Percentage of injury to drop peaches, Siloam Springs, Ark., 1908.*

Dates fruit was collected.	Fruits.	Fruits infested.
Apr. 30	2,500	1,481
May 9	6,500	674
16-19	30,840	1,658
21	7,200	958
25	2,400	301
30	498	89
June 3	198	80
8	135	56
13	251	67
17	68	19
22	101	25
27	21	7
July 1	16	2
5	41	15
11	90	50
15	104	30
20	689	300
25	648	87
29	328	21
Total	52,628	5,920

Average per cent of infestation, 11.25.

The degree of infestation by the curculio of all fallen fruit for the season from 10 peach trees in the District of Columbia is shown in Table LXXVI. The percentage of infestation, 44.73, closely approximates the averages of the figures in Table LXXIV.

TABLE LXXVI.—*Percentage of injury to drop peaches, Washington, D. C., 1908.*

Dates fruit was collected.	Number of fruits.	Number of fruits infested.
May 24	676	342
June 5	2,500	1,202
10	902	290
16	247	124
July 3	79	12
Total	4,404	1,970

Average per cent of infestation, 44.73.

Extent of injury to miscellaneous sorts of plums is indicated in Table LXXVII. Records were made by gathering the specified number of fruits here and there from the trees or from the ground. It is regretted that similar data are not available from more northern localities.

TABLE LXXVII.—*Percentage of injury to plums by egg and feeding punctures, various localities.*

Localities.	Varieties.	Date collected.	Fruits with egg punctures.	Fruits with feeding punctures.	Uninjured fruit.	Total number of fruit.	Average percentage of fruit injured.	Remarks.
		1908.						
Myrtle, Ga.	Wild plum	Apr. 9	22	14	164	200		From trees.
Do.	do.	13	37	14	49	100		Do.
Do.	do.	20	43	6	51	100		Do.
Do.	do.	22	36	10	4	50		From ground.
Do.	do.	30	36	5	9	50		From trees.
Do.	do.	30	43	4	3	50		From ground.
Do.	do.	May 8	36	4	10	50		From tree.
Do.	do.	8	32	5	13	50		From ground.
Do.	do.	31	22	5	23	50		From tree.
Do.	do.	31	34	4	12	50		From ground.
Do.	do.	June 6	27	3	20	50		From tree.
Do.	do.	6	40	8	2	50		From ground.
Do.	do.	11	28	2	20	50		From tree.
Do.	Red June	Apr. 9	4	6	90	100		Do.
Do.	do.	14	61	13	26	100		Do.
Do.	do.	May 7	3	5	17	25		Do.
Do.	do.	7	32	3		35		From ground.
		1905.						
Arundel, Md.	Burbank	May 9	33	12	55	100		From tree.
Do.	do.	9	63	25	112	200		Do.
Riverdale, Md.	(?)	26	117	4	18	139		Do.
Do.	(?)	26	122		2	124		From ground.
Bennings, D. C.	(?)	22	30	9	61	100		From tree.
Do.	(?)	22	35	10	5	50		From ground.
Total for all localities.			936	171	766	1,873	59.10	

In the above table the figures for injury show merely the number of punctures. While most of the fruit punctured would fall, not all of it would do so, the fruit more or less outgrowing the injury. The average percentage of injury, i. e., 59.10, is therefore perhaps a little high.

The extent to which pears may be punctured is shown for two localities in Table LXXVIII. As elsewhere explained, the real injury to such pears as Le Conte and Kieffer is small, as the thinning of the young fruit is in most cases desirable and the punctures are mostly outgrown by the fruit on the trees.

TABLE LXXVIII.—*Percentage of injury to pears by egg and feeding punctures, Georgia and Maryland.*

Localities.	Varieties.	Date collected.	Fruits with egg punctures.	Fruits with feeding punctures.	Uninjured fruit.	Total number of fruit.	Average percentage of fruit injured.	Remarks.
		1906						
Myrtle, Ga.	LeConte	Apr. 9	11	7	182	200		From trees.
Do.	do	9		12	188	200		From ground.
Do.	do	14	7		93	100		From tree.
Do.	do	14	4	10	86	100		From ground.
Do.	do	20	11	4	35	50		From tree.
Do.	do	20	4	2	44	50		From ground.
Do.	do	May 2	19	3	28	50		From tree.
Do.	do	4	10	3	37	50		From ground.
Do.	do	31	7	8	35	50		From tree.
Do.	Keiffer	Apr. 4	18	22	160	200		Do.
Do.	do	9	18	9	173	200		Do.
Do.	do	9	3	5	152	160		From ground.
Do.	do	13	29	12	59	100		From tree.
Do.	do	13	9	7	84	100		From ground.
Do.	do	20	25	2	23	50		From tree.
Do.	do	20	13	3	34	50		From ground.
Do.	do	May 2	16	5	29	50		From tree.
Do.	do	4	18	7	25	50		From ground.
Do.	do	31	10	12	28	50		From tree.
Arundel, Md.	Bartlett	12			25	45		Do.
Do.	Keiffer	12			42	127		Do.
Total and average per cent of injury for both localities.			232	133	1,562	2,032	23.12	

The extent of injury to apples in several localities during 1908 and 1909 is shown in Table LXXIX. These records are from unsprayed or control trees used in spraying experiments and demonstrations against the codling moth and plum curculio, and are further referred to under the heading of spraying apples (p. 193).

TABLE LXXIX.—*Number of egg and feeding punctures and percentage of injury to apples, including drop fruit and fruit from tree, various localities, for seasons 1908 and 1909.*

Localities.	Variety.	Date.	Tree No.	Egg punctures.	Feeding punctures.	Injured fruit.	Total number of fruit.	Average percentage of fruit injured.
Anderson, Mo.	Lansingburg	Season 1908.	1	1,486	438	166	169	
Do.	do	Season 1908.	2	1,502	542	298	308	
Do.	do	Season 1908.	3	1,492	381	219	235	
Do.	do	Season 1908.	4	1,615	448	284	298	
Do.	do	Season 1908.	5	1,910	539	389	400	
Do.	do	Season 1908.	6	1,882	573	344	368	
Do.	do	Season 1908.	7	2,547	907	544	585	
Do.	do	Season 1908.	8	2,142	599	484	516	
Do.	do	Season 1908.	9	2,021	752	566	626	
Total and average per cent of injury.				16,657	5,179	3,294	3,505	93.98
Douglas, Mich.	Ben Davis	Season 1908.	1	538	301	274	751	
Do.	do	Season 1908.	2	916	282	316	592	
Do.	do	Season 1908.	3	1,241	740	528	944	
Do.	Hubbardstown	Season 1908.	4	1,778	780	458	933	
Do.	do	Season 1908.	5	2,343	1,121	1,012	3,003	
Do.	Oldenberg	Season 1908.	6	9,482	891	1,079	1,132	
Do.	do	Season 1908.	7	4,627	496	1,285	1,632	
Total and average per cent of injury.				20,925	4,611	4,952	8,987	55.10

TABLE LXXIX.—*Number of egg and feeding punctures and percentage of injury to apples, including drop fruit and fruit from tree, various localities, for seasons 1908 and 1909*—Continued.

Localities.	Variety.	Date.	Tree No.	Egg punctures.	Feeding punctures.	Injured fruit.	Total number of fruit.	Average percentage of fruit injured.
Westfield, N. Y.	Baldwin	Season 1908.	1	139	52	181	748	
Do	do	Season 1908.	2	169	140	298	1,518	
Do	do	Season 1908.	3	119	62	283	881	
Do	do	Season 1908.	4	147	65	212	1,100	
Do	do	Season 1908.	5	191	121	286	838	
Total and average per cent of injury.				765	440	1,260	5,085	24.77
Crozet, Va.	Yellow Newtown.	Season 1909.	1	1,670	1,076	1,255	3,423	
Do	do	Season 1909.	2	1,627	944	1,571	3,682	
Do	do	Season 1909.	3	479	226	437	816	
Do	do	Season 1909.	4	631	331	531	1,016	
Do	do	Season 1909.	5	1,419	1,071	1,415	3,111	
Do	do	Season 1909.	6	1,068	871	1,193	2,988	
Do	do	Season 1909.	7	1,433	865	1,285	2,091	
Do	do	Season 1909.	8	1,170	695	1,098	1,980	
Total and average per cent of injury.				9,497	6,079	8,785	19,107	45.97
Fisherville, Va.	Winesap	Season 1909.	1	1,326	536	1,350	4,463	
Do	do	Season 1909.	2	727	389	799	3,134	
Do	do	Season 1909.	3	1,718	518	1,378	3,537	
Do	do	Season 1909.	4	1,573	378	1,420	4,055	
Do	do	Season 1909.	5	2,793	795	2,307	5,892	
Do	do	Season 1909.	6	1,019	206	803	2,244	
Total and average per cent of injury.				9,156	2,822	8,057	23,325	34.53
Mount Jackson, Va.	Ben Davis	Season 1909.	1	5,119	2,217	3,186	3,926	
Do	do	Season 1909.	2	3,545	952	2,226	3,109	
Do	do	Season 1909.	3	1,703	509	1,079	1,840	
Do	do	Season 1909.	4	2,179	709	1,226	1,508	
Do	do	Season 1909.	5	3,723	1,307	2,399	3,189	
Do	do	Season 1909.	6	4,113	2,009	2,823	4,153	
Do	do	Season 1909.	7	5,541	3,238	3,611	5,121	
Do	do	Season 1909.	8	3,785	1,199	2,107	2,795	
Total and average per cent of injury.				29,708	12,140	18,657	25,641	72.72

The injury indicated for apples ranges from 93.88 to 24.77 per cent of the total crop, both dropped and picked fruit. It is not to be inferred that the figures indicate the actual amount of fruit lost from curculio attack, since in many instances in the case of fruit from trees there would be but a single feeding puncture, or an old egg scar, largely outgrown. Such specimens, while unfit for fancy market fruit, would possess considerable value.

NATURAL ENEMIES.

There are many factors which taken collectively exert an important influence on the numbers of the curculio, as unfavorable conditions during the winter, drought during pupal period and time of emergence of beetles from the soil, scarcity of fruit for oviposition due to frosts or other causes, and the influence of parasitic and predaceous enemies and disease. Notwithstanding all of these, the insect is able to main-

tain itself most successfully, and puts in its appearance in the spring in numbers with much regularity. Under favorable conditions for development, as in neglected orchards, they often become excessively abundant, but for any locality do not show as a rule any great variation in numbers from season to season. Although the curculio in its egg, larval, and pupal stages lives well protected—as in the fruit and below the soil—yet it is subject to the attack of several species of parasites.

PARASITIC INSECTS.

(Anaphes) Anaphoidea conotracheli Girault.

Only one parasite of the egg of the curculio is known, namely, (*Anaphes*) *Anaphoidea conotracheli* Girault, first reared by the senior author in 1902 at College Park, Md., and next from material collected in 1905 at Fort Valley, Ga. (See fig. 25.) The description of this species by Girault will be found in Entomological News.[1] These minute insects, barely visible to the naked eye, are quite active, jumping readily when disturbed. This parasite appears to be widely distributed, and has been reared from eggs of the plum curculio in the fruits indicated, from the following localities:

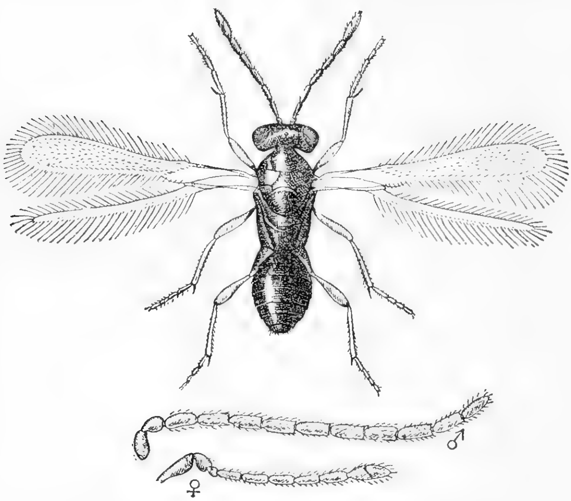


FIG. 25.—(*Anaphes*) *Anaphoidea conotracheli*, an egg parasite of the plum curculio. (Original.)

TABLE LXXX.—*Records of rearings of* (*Anaphes*) *Anaphoidea conotracheli, various localities.*

Localities.	Date.	Fruit.
Berlin, Conn	July 3-18, 1905	Plum.
Washington, D. C	May 9-31, 1905	Plum, apricot.
College Park, Md	July 22-29, 1905	Apple.
Riverdale, Md	May 3-July 24, 1905	Apple, plum.
Arundel, Md	May 16-June 15, 1905	Peach, pear, plum.
Arlington, Va	June 13-July 13, 1905	Peach, cherry, apple.
Alexandria, Va	June 15-16, 1905	Apple, cherry.
East Falls Church, Va	Aug. 12, 1905	Apple.
Victoria, Tex	June 15, 1905	Plum.
Tryon, N. C	May 20, 1905	Do.
Lexington, Ky	June 18, 1905	Do.
Ardmore, Okla	May 30, 1905	Wild plum.
Fort Valley, Ga	May 9-June 28, 1905	Wild plum, Japan plum.
Myrtle, Ga	Apr. 26-May 13, 1906	Wild plum.
Charlottesville, Va	May 18, 1905	Apple.
Barnesville, Ga	May 17-26, 1910	Wild plum.

[1] Ent. News, vol. 16, p. 220 (1905).

From the records from localities in the environs of Washington, (College Park, Riverdale, Arundel, Md., and Arlington, Alexandria, and East Falls Church, Va.) it would appear that the insect is out ovipositing nearly coincident with the period of oviposition of its host, namely, May 3 (Riverdale, Md.) to August 12 (East Falls Church, Va.). Rearings have been made from eggs in various fruits, including wild and cultivated plum, and it is probable that the parasite will search out eggs in any fruit used by the curculio for egg laying.

In its distribution the Anaphoidea is seen to range pretty well over the Eastern States, and rearings from Ardmore, Okla., indicate its occurrence in the Southwestern States. The insect probably follows its host, though no data of note are at hand as to its distribution in the Mississippi Valley and Middle-Western States.

In several instances it was possible to determine the percentage of parasitism of the eggs. Thus, in a lot of eggs from Arundel, Md., in plums collected from trees May 9, 62.8 per cent yielded adults of the Anaphoidea. In another lot from the same locality, on the same date and host, the parasitism amounted to 70.76 per cent. A lot from Berlin, Conn., in plum, gave about 85 per cent parasitism.

At Myrtle, Ga., eggs in wild plum collected May 16 gave 10 per cent, and another lot taken May 1 gave 16.6 per cent parasitized. From Bennings, D. C., a lot of eggs in plum taken May 31 gave 12.2 per cent parasitized.

Of 36 eggs collected at Barnesville, Ga., May 17, 36.11 per cent gave out adult parasites. In a lot of 28 eggs collected May 19 the percentage was 46.43, and of 97 eggs collected May 26 the percentage producing adult parasites was 56.70. In these three lots, if account be taken only of the eggs which either hatched or gave out adult parasites, the proportions parasitized would be 46.43 per cent, 76.47 per cent, and 91.66 per cent. Five eggs in these lots produced two parasites each.

Certain observations on the habits and biology of the Anaphoidea parasites, made by Mr. Girault, are of interest, especially in view of the paucity of our knowledge concerning these minute creatures. Parasitized eggs were found to maintain their normal pale white color until within two days of the emergence of the parasite, at which time or a little later the large reddish eyes and the three reddish ocelli between them become evident and the general outline of the parasite becomes discernible. Gradually the parasite becomes dusky and a few hours before emergence almost entirely black. The time required for the development of Anaphoidea from egg to adult varied from 9 to 11 days, averaging approximately 10 days. Thus during the 6 to 8 weeks of egg laying of the curculio there would be time for six or seven generations of the parasite.

Oviposition was observed several times. In a typical instance, the female carefully examined the egg puncture, which was two days old; the long flexible antennæ moved alternately up and down very

rapidly, tapping the plum. After an instant of greater excitement she suddenly stopped, with body raised, holding the antennæ straight and rigid before her. The slender ovipositor was quickly inserted, the tip of abdomen being bent cephalad for the purpose. Oviposition occurred within 30 seconds. In removing the ovipositor the antennæ were lowered partly beneath the fore-body, evidently as a help, and the abdomen quickly arched.

(Sigalphus) Triaspis curculionis Fitch.

The Sigalphus parasite of the curculio (fig. 26) was first discovered by Dr. Fitch, and a description with figure of the female published in the Country Gentleman for October, 1859 (p. 221), and also in the Albany Cultivator in October of the same year. A more extended account is given in his address "On the curculio and black knot on plum trees," delivered before the New York Agricultural Society in 1860. The specimens upon which the description was based came from D. W. Beadle, St. Catherines, Ontario, and had been reared by him from black knot on plum trees which were infested with curculio larvæ, the adult curculios appearing in numbers in the rearing jars. The fact that the black knot is also infested by the larvæ of other insects, especially that of the so-called plum moth (*Enarmonia prunivora* Walsh), casts doubt on the exact host relations of the Sigalphus. In fact, Walsh in his report as acting entomologist of Illinois ridiculed the idea that the Sigalphus was a parasite of the curculio, and this doubt was not removed until 1870, when Dr. Riley reared the insect in large numbers from curculio larvæ placed in jars in carefully sifted earth.

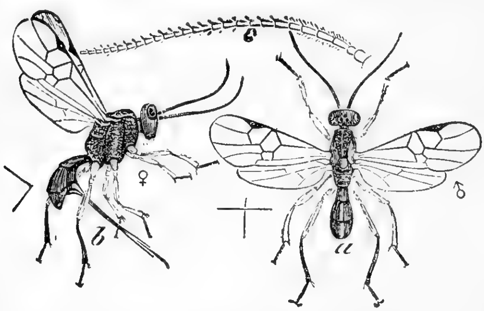


FIG. 26.—(*Sigalphus*) *Triaspis curculionis*, an important parasite of the plum curculio: *a*, Male; *b*, female; *c*, antenna. (After Riley.)

Little has been added to our knowledge of this insect since the observations by Riley. Prof. Gillette, in Iowa Station Bulletin 9, page 378, gives some interesting notes on the insect; he found it quite common in the vicinity of Ames during the summer of 1889. The variety *rufus* Riley, later mentioned, was four times as abundant as the true *curculionis*. The substance of the same article was also published in the Canadian Entomologist, volume 22, page 114 (1890).

The Sigalphus has been reared by Fayville and Parrot, in Kansas, from larvæ of the potato stalk weevil, *Trichobaris trinotata* Say (Kansas Station Bulletin 82, p. 12), and the parasite is recorded from the same host by Dr. Chittenden (Bul. 33, n. s., Bur. Ent.,

U. S. Dept. Agr., p. 17). The insect was reared from the cotton boll weevil (*Anthonomus grandis*) at Calvert, Tex., and is doubtfully recorded from *Conotrachelus juglandis* Lec. Specimens of *curculionis* were also received from Prof. A. H. Conradi, Clemson College, S. C., in 1908, and from Prof. Fred E. Brooks, Morgantown, W. Va., January, 1907, who had reared them from *Balaninus* sp. As stated by Mr. W. D. Pierce (Journ. Econ. Ent., vol. 1, p. 386), it commonly attacks *Conotrachelus elegans* Boh., at Dallas and Victoria, Tex. At Four Mile Run, Va., it was reared from *Trichobaris trinotata* Say in eggplant. Riley records the Sigalphus from a stalk-borer in Ambrosia (Ins. Life, vol. 2, p. 353). In West Virginia it has been reared in abundance from *Conotrachelus affinis* Boh. and in lesser numbers from *C. juglandis* Lec. (W. Va. Agr. Exp. Sta., Bul. 128. p. 182).

This, so far as the writers know, is the complete host list of the species, and Sigalphus is so much more common on *Conotrachelus nenuphar* that this is without doubt its principal host.

(*Sigalphus*) *Triaspis curculionis* is of general occurrence througnout eastern North America, its range probably being coextensive with that of the plum curculio. A list of localities, with dates of rearing, is given in Table LXXXI.

TABLE LXXXI.—*Distribution of (Sigalphus) Triaspis curculionis, with dates of rearing.*

Localities.	Dates of emergence.	Localities.	Dates of emergence.
New Haven, Conn	July 12-18, 1905.	Fort Valley, Ga	May 22-July 3, 1905.
Youngstown, N. Y	July 14-Aug. 18, 1905.	Myrtle, Ga	June 10, 1906.
North East, Pa	July 8-14, 1906.	Barnesville, Ga	May 23-June 30, 1910.
New Richmond, Ohio	June 24-July 12, 1907.	Lake City, Fla	May 23, 1905.
East Lansing, Mich	July 21, 1905.	Hampton, Fla	May 31, 1905.
Valparaiso, Ind	July 18, 1905.	Garrison, Tex	June 15, 1905.
Arundel, Md	June 21-July 26, 1905.	Mexia, Tex	June 18, 1905.
Riverdale, Md	June 16-July 6, 1905.	Siloam Springs, Ark	June 3-July 18, 1908.
Washington, D. C	May 22-July 17, 1905.	Bentonville, Ark	June 24-26, 1906.
Do	June 24-July 30, 1908.	Ozark, Ark	June 21-July 8, 1905.
Arlington, Va	June 2-July 30, 1905.	Salina, Kans	July 22, 1910.
Winchester, Va	June 15-17, 1905.	Grand Island, Nebr	July 18-22, 1910.
Raleigh, N. C	June 20, 1905.	North Platte, Nebr	Do.
Tryon, N. C	Do.		

Localities in literature:
St. Catherines, Ontario (Fitch).
St. Louis, Mo. (Riley).
Ames, Iowa (Gillette).

The insect has been reared from many localities during the past four or five years, exclusively from plum curculio larvæ, but never in noteworthy numbers, although the degree of parasitism in a few cases reached 25 per cent. This would vary, perhaps, depending upon when the infested fruits were collected, as larvæ are parasitized principally in early spring. In three records that covered the entire season the average infestation was 2.78 per cent.

In connection with the records of emergence of larvæ from fruit for the season in the insectary yard and other data (see p. 62), ac-

count was taken of the emergence of this parasite from the soil boxes, as shown below:

TABLE LXXXII.—*Record of emergence of (Sigalphus) Triaspis curculionis from plum curculio larvæ for season, Washington, D. C., 1908.*

Lot No.	Date larvæ placed in soil.	Larvæ placed in soil.	Sigalphus emerging.	Percentage of larvæ parasitized.	Beetles emerging.	Percentage of larvæ transforming to adults.	Percentage of larvæ unaccounted for.
1	May 27	187			85	45.45	54.55
2	28	283	2	0.71	103	36.40	62.89
3	30	218	15	6.88	38	17.43	75.69
4	31	297	4	1.34	25	8.41	90.25
5	June 1	281	15	5.34	71	25.27	69.39
6	2	206	10	4.86	37	17.96	77.18
7	3	162	4	2.47	7	4.32	93.21
8	4	90	10	11.11	24	26.67	62.22
9	5	174	2	1.15	20	11.49	87.36
10	6	243	15	6.17	4	1.65	92.18
11	7	208	3	1.44	6	2.88	95.68
12	8	203	1	.49	5	2.46	97.05
13	9	157	2	1.27	37	23.57	75.16
14	10	154	3	1.95	17	11.04	87.01
15	11	249			14	5.62	94.38
16	12	369	2	.54	84	22.76	76.70
17	13	172	4	2.33	84	48.84	48.83
18	14	190	1	.53	42	22.11	77.36
19	15	140			6	4.29	95.71
20	16	296	1	.34	52	17.57	82.09
21	17	107	1	.93	19	17.76	81.31
22	18	60	1	1.67	20	33.33	65.00
23	19	122			39	31.97	68.03
24	20	106	1	.94	31	29.25	69.81
25	21	139	3	2.16	18	12.95	84.89
26	22	175			29	16.57	83.43
27	24	177	1	.56	11	6.21	93.23
28-59	June 25-Aug. 1	860			185	21.51	78.49
Total		6,025	101	1.68	1,113	18.47	79.85

The percentage of parasitism, it will be noted, varied widely—from less than one-half of 1 per cent to 11.11 per cent on June 4. The average percentage of parasitism for the season is small, and it seems probable that the insect during 1908 was less abundant than normal.

Similar records of parasites emerging from lots of larvæ taken over the whole season from Elberta peaches were made at Siloam Springs, Ark., during 1908, as set forth in Table LXXXIII.

TABLE LXXXIII.—*Record of emergence of (Sigalphus) Triaspis curculionis for season, Siloam Springs, Ark., 1908.*

Lot No.	Date larvæ entered soil.	Larvæ.	Sigalphus emerging.	Percentage of larvæ parasitized.	Beetles emerging.	Percentage of larvæ transforming to adults.	Percentage of larvæ unaccounted for.
1	May 12-16	328	3	0.91	50	15.24	83.85
2	May 17-19	573	18	3.14	124	21.64	75.22
3	May 20-22	965	21	2.18	131	13.58	84.27
4	May 23-25	550	19	3.45	123	22.36	74.19
5	May 26-28	629	18	2.86	253	40.22	56.92
6	May 29-31	719	7	.97	211	29.35	69.68
7	June 1-3	532	5	.94	293	55.08	43.98
8	June 4-6	449	1	.22	124	27.62	72.16
9-10	June 7-12	394			102	25.89	74.11
11	June 13-15	107	4	3.74	49	45.79	50.47
12	June 16-18	81	4	4.94	50	61.73	33.33
13	June 19-21	61	2	3.28	34	55.74	40.98
14-23	June 22-Aug. 13	637			230	36.11	63.89
Total		6,025	102	1.69	1,774	29.44	68.87

Here also the percentage of parasitism varies with the different lots, but is less than in case of material from Washington. The average parasitism for the season was 1.69 per cent, approximately the same as that from Washington. This would be of but little importance as affecting the abundance of the curculio.

At Barnesville, Ga., in 1910, data of the same character were obtained from all the larvæ infesting the fruit on a block of 31 Elberta peach trees during the season, as shown in Table LXXXIV. These data show a considerably higher percentage of parasitism and also a larger percentage of larvæ transforming to adults, with a corresponding decrease in the proportion of larvæ failing to produce either parasites or beetles. This was doubtless due to a more favorable condition of the soil in the rearing cages.

TABLE LXXXIV.—*Record of emergence of Sigalphus curculionis for season, Barnesville, Ga., 1910.*

Lot No.	Date larvæ entered soil.	Number of larvæ.	Number of Sigalphus emerging.	Percentage of larvæ parasitized.	Number of beetles emerging.	Percentage of larvæ transforming to adults.	Percentage of larvæ unaccounted for.
1	May 2–3	77	20	25.97	28	36.36	37.67
2	May 4–6	457	96	21.01	182	39.82	39.17
3	May 7–9	566	47	8.30	276	48.76	42.94
4	May 10	240	11	4.58	105	43.75	51.67
5	May 11	209	8	3.83	109	52.15	44.02
6	May 12	272	11	4.04	170	62.50	33.46
7	May 13	159	4	2.52	117	73.59	23.89
8	May 14–16	192	4	2.08	145	75.52	22.40
9	May 17–19	142	3	2.11	101	71.13	26.76
10	May 20–23	190	7	3.68	108	56.84	39.48
11	May 24–26	66	1	1.52	45	68.18	30.30
12	May 27–29	33	0	....	21	63.64	36.36
13	May 30–June 1	28	0	....	13	46.43	53.57
14	June 2–8	26	1	3.85	15	57.69	48.46
15 to 29	June 9–Aug. 9	258	0	....	133	51.55	48.45
Total	May 2–Aug. 9	2,915	213	7.31	1,568	53.79	38.90

Observations on miscellaneous lots of larvæ at Youngstown, N. Y., in 1905 (see Table LXXXV) show a much higher percentage of parasitism, the average for all lots being 18.66 per cent parasitized. These records, however, are not made from proportionate numbers of larvæ throughout the season. The parasites were perhaps at their greatest abundance during the period under observation.

TABLE LXXXV.—*Record of emergence of (Sigalphus) Triaspis curculionis from miscellaneous lots of larvæ, Youngstown, N. Y., 1905.*

Lot No.	Date larvæ entered soil.	Number of larvæ.	Number of Sigalphus emerging.	Percentage of larvæ parasitized.
1	June 27	10	1	10.00
2	...do....	40	8	20.00
3	June 28	55	15	27.27
4	June 29	80	20	25.00
5	...do....	20	8	40.00
6	...do....	150	35	23.33
7	July 1	150	20	13.33
8	July 2	126	15	11.90
9	July 3	135	20	14.81
10	July 7	70	14	20.00
Total	....	836	156	18.66

In reality, however, the percentage of parasitism, as shown in these several tables, is too low, since it is based on the total number of larvæ which were placed in pots of soil or other container. In all rearing work a considerable proportion of larvæ, aside from those killed by parasites, failed to develop to adults, from various causes, as immaturity, etc. Taking the total emergence of beetles and parasites as a basis, the percentage of parasitism for the season of 1908 at Washington, D. C., was 8.32; at Siloam Springs, Ark., 5.44; and at Barnesville, Ga., in 1910 it was 11.96. Even these figures are probably too low, since the removal of the infested fruit from the orchard to the laboratory must have prevented a certain degree of parasitism that would normally have occurred in fruit lying exposep in the orchard.

(**Sigalphus**) **Triaspis curculionis** var. **rufus** Riley.

This variety was described in his Third Missouri Report, page 27, by Riley, who states that it is slightly larger and differs so remarkably from the normal form that were it not for the absolute correspondence of all of the sculpturing of the thorax and body, and the venation of the wings, it might be considered distinct. The great length of the ovipositor is very characteristic. Concerning this variety in Iowa Prof. Gillette observes (Canadian Entomologist, vol. 22, p. 114):

> The variety *rufus* appeared much more abundant than *curculionis* in my breeding cages last summer. The two forms differ so much from one another, and in some respects, especially in the number of joints of the antennæ, from Riley's description that I have made the following notes upon them. "* * * *Rufus* is decidedly more robust in every case than *curculionis*, and were it not for the fact that so eminent an authority as Dr. Riley considers them the same species, I should think that *rufus* ought to be raised to the rank of a species."

Attempts were made by Prof. Riley to distribute both the Sigalphus and Porizon parasites, specimens being sent to several correspondents from Kirkwood, Mo. In the bureau collection of Sigalphus reared from the curculio, 725 specimens, only 40 are of the *rufus* variety, from the following localities: Fort Valley, Myrtle, and Barnesville, Ga.; Valparaiso, Ind.; Arlington, Va.; Riverdale, Md.; Washington, D. C., and Siloam Springs, Ark. These, with its recorded occurrence in Missouri and Iowa, indicate a distribution similar to that of *curculionis*.

It appears from observations made at Barnesville, Ga., in 1910 that while practically all of the typical forms emerge from the earliest larvæ, the variety *rufus* only reaches its full numbers very late in the season, after *curculionis* has ceased to appear. A few isolated specimens of *rufus* emerged in connection with the typical form from material from Elberta peaches, but most of them were

reared much later from other material. From 240 curculio larvæ which entered the soil August 30 to October 15 there emerged 16 specimens of *rufus* from September 24 to October 23. This gives a percentage of parasitism of 6.66. No other kinds of parasites emerged from these late larvæ, while the proportion and number of *rufus* were larger than at any previous time.

(Porizon) Thersilochus conotracheli Riley.

This ichneumonid parasite of the curculio (see fig. 27) was described by Riley in 1871 (Third Missouri Report, p. 28) from specimens reared from cocoons sent him by Dr. Trimble, of New Jersey. The parasite feeds upon the curculio larva, and while developing to the adult form in the fall, remains in the cocoon until the following spring. This habit of overwintering in the soil perhaps has contributed to its general oversight by persons who have reared curculios, for there are very few references in literature concerning it. Five specimens of adults of this species were dissected from cocoons by Mr. Johnson, at Youngstown, N. Y., August 24 and October 2, 1908, and on October 4 of the same year a total of 76 cocoons of this parasite was found in curculio rearing jars, in which had been placed a total of 836 curculio larvæ, giving a percentage of parasitism for this species of 9.09. Mr. Johnson also succeeded in rearing this species from material kept over winter. On October 5, 1905, 55 cocoons were found in a jar for breeding curculios at Youngstown, N. Y. This jar was again examined May 18, 1906, by which time 11 adult parasites had emerged. Forty-eight cocoons were found in a jar in which had been placed 549 curculio larvæ, at North East, Pa., August 24, 1906.

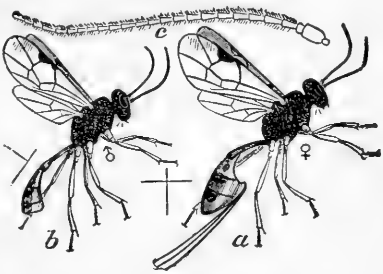


FIG. 27. (*Porizon*) *Thersilochus conotracheli*, parasitic upon the plum curculio: *a*, Female; *b*, male. (From Riley.)

Dr. Riley evidently reared this species, along with (*Sigalphus*) *Triaspis curculionis*, in numbers in Missouri, for he speaks of having distributed specimens of each, from Kirkwood, to several localities. The insect is recorded by Dr. Howard from Coon Island, Pa., in 1887, and Riley and Howard (Rept. Com. Agr., 1888, p. 64) refer to receipt of specimens from a correspondent who found them ovipositing and regarded them as a new enemy of the plum. Prof. Gillette, in his curculio studies in Iowa, makes no reference to Porizon, which presumably was not observed. The species is probably of much less economic importance than the preceding, though, as

stated, its habit of wintering in the cocoon may have caused it to have been overlooked. Specimens are in the U. S. National Museum from Long Island and Oswego, N. Y., Connecticut, southern Illinois, Missouri, and Onaga, Kans.

(Bracon) Microbracon mellitor Say.

A specimen of (*Bracon*) *Microbracon mellitor* (fig. 28) was reared from the plum curculio by Prof. F. E. Brooks at French Creek, W. Va., in 1902 (U. S. Dept. Agr., Div. Ent., Bul. 38, n. s., p. 109). In 1905 it was again reared from the plum curculio at Youngstown, N. Y., North East, Pa., Arundel, Md., and Fort Valley, Ga. Observations by Mr. Fred Johnson at Youngstown, N. Y., and North East, Pa., indicate that this parasite lives externally upon the curculio larva, destroying the latter before it leaves the fruit. The cocoon of the parasite is then formed within the fallen fruit.

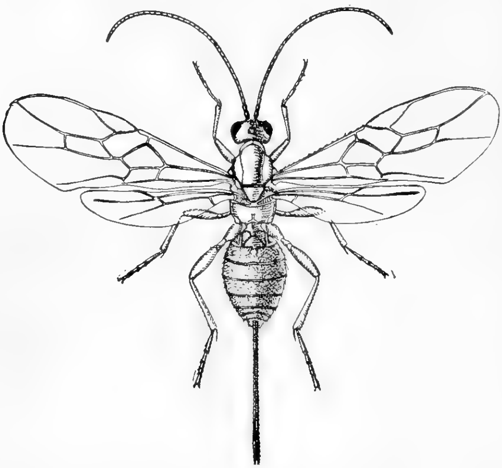


FIG. 28.—(*Bracon*) *Microbracon mellitor*, an occasional parasite of the plum curculio. (From Hunter and Hinds.)

Bracon dorsata Say.

Several specimens of this insect were reared from curculio-infested plums from Arundel, Md., Washington, D. C., and Lexington, Ky. Other insects were also present, and there is a doubt that this species is a parasite of the plum curculio.

Other Hymenopterous Parasites.

A chalcidid of the genus Eurytoma was reared from *Conotrachelus nenuphar* at French Creek, W. Va., in 1902 (U. S. Dept. Agr., Div. Ent., Bul. 38, n. s., p. 109). At North East, Pa., 4 specimens of a species of *Anisocyrta* (Braconidæ) emerged, July 24, 1906, from the soil in a jar in which curculio larvæ were transforming. An ichneumon fly, *Pimpla* (*Epiurus*) sp., was also reared at North East, Pa., from curculio-infested prunes, 3 specimens emerging July 9–23, 1906. What is very likely the same species was reared at Youngstown, N. Y., in 1905. The parasite destroyed a curculio larva in a small apple and formed a cocoon in the dropped fruit. At Vienna, Va., during 1911, Mr. R. A. Cushman reared the following from the curculio: *Eurytoma* sp., *Catalaccus* sp., *Cerambycobius* sp., and *Microbracon lixi* Ashm., which was next in abundance to *Triaspis curculionis*.

Myiophasia ænea Wiedemann.

This tachinid fly (fig. 29) is a widely distributed parasite of the larvæ of several species of weevils, including the plum curculio. It is a very variable species, having been described and recorded under many names. The species was first described from Montevidio, Uruguay, South America, but has since been found in Central America, Mexico, and all sections of the United States. In the collections of the National Museum and the Bureau of Entomology there are specimens from the following localities: Chinandega, Nicaragua; City of Mexico, Mexico; Sierra Madre, Chihuahua, Mexico; Pecos, N. Mex.; Beulah, N. Mex.; Corvallis, Oreg.; St. Louis, Mo.; Dallas, Tex.; Baton Rouge, La.; Inverness, Fla.; Tifton, Ga.; Barnesville, Ga.; Clemson College, S. C.; Arundel, Md.; White Mountains, N. H.; Douglas, Mich.

Other recorded localities are: Santa Fe, N. Mex.; Charlotte Harbor, Fla.; New Jersey; Massachusetts; Gypsum, Ohio; Constantine, Mich.; Carlinville, Ill.; South Dakota.

It is thus seen that the species extends greatly beyond the range of the plum curculio, subsisting on other hosts. Riley, Lugger, and Pergande reared *Myiophasia ænea* from *Balaninus uniformis* Lec., at St. Louis, Mo., in 1876. In 1886 Pergande reared it at Washington, D. C., from *Conotrachelus elegans* Say, infesting young twigs of hickory. Parasites reared by Forbes from *Sphenophorus parvulus* Gyll., and a cutworm (*Heliophila unipuncta* Haw.) were identified under one of the synonyms of *M. ænea* (Psyche, vol. 6, p. 467), but it is probable that there was an error in recording it as a parasite of *Heliophila unipuncta*, there being no other known instance of *M. ænea* attacking anything but weevil larvæ. At Gypsum, Ohio, Webster found *M. ænea* as a parasite of *Ampeloglypter sesostris* Lec. (Ent. News, vol. 10, p. 53, pl. 3). In this case a secondary parasite (*Calyptus tibiator*) was reared from *M. ænea*. More recently Pierce (Journ. Econ. Ent., vol. 1, p. 381) has reared *M. ænea* from the boll weevil (*Anthonomus grandis* Boh.) and from *Conotrachelus elegans* Say at Dallas and Victoria, Tex. In the National Museum are many specimens of *M. ænea* reared from *Chalcodermus æneus* Boh. by G. G. Ainslee, Clemson College, S. C. It had previously been reared from a species of Chalcodermus by H. A. Morgan at Baton Rouge, La.

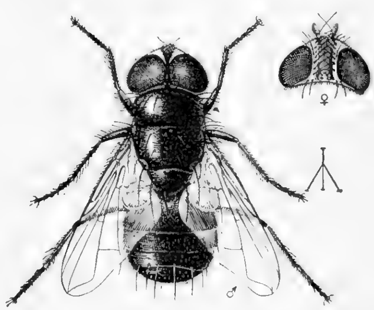


FIG. 29.—*Myiophasia ænea*, a dipterous plum curculio parasite: Male and head of female. (From Ainslie.)

So far as known *M. ænea* was first obtained as a parasite of the plum curculio by Mr. A. A. Girault, who reared a single specimen from curculio-infested peaches collected at Arundel, Md., June 29, 1905. In 1908 another specimen was reared from the plum curculio in cherries by R. W. Braucher at Douglas, Mich. At Barnesville, Ga., 13 specimens were reared from 1,115 curculio larvæ from peaches collected on August 5, 1910. The larvæ entered the soil August 6 to 13, and the parasites emerged from August 29 to September 5. This species must be considered as only an occasional parasite of the plum curculio, the highest known percentage of parasitism being 1.16 in the case of the lot reared at Barnesville, Ga. A few specimens of this fly were reared from curculio larvæ by R. A. Cushman during 1911, at Vienna, Va.

Cholomyia inæquipes Bigot.[1]

Like the preceding species, *Cholomyia inæquipes* (fig. 30) is a very widely distributed parasite of weevil larvæ. It was first described by Fabricius from South America in 1805 as *Musca longipes*, and later by Bigot from Mexico under the name of *C. inæquipes*. Specimens are in the National Museum and in the Bureau of Entomology collections from the following localities: Frontera, Tabasco, Mexico; Dallas, Tex.; Lawrence, Kans.; St. Louis, Mo.; Siloam Springs, Ark.; Mound, La.; Fort Valley, Ga.; Barnesville, Ga.; Peaks of Otter, Va.; Arlington, Va.; Arundel, Md.; Lexington, Ky.; West Virginia; North East, Pa.

This insect was first reared by Riley at St. Louis, Mo., under circumstances indicating that it was a parasite of the plum curculio. In 1897 it was reared at Mound, La., from *Conotrachelus juglandis* Lec. *Metadexia basalis* Giglio-Tos, which Mr. D. W. Coquillett regards as probably a synonym of *C. inæquipes*, has been reared from *Conotrachelus juglandis* in West Virginia. Pierce has reared *C. inæquipes* from *Conotrachelus elegans* Boh., at Dallas, Tex. At Siloam Springs, Ark., it has been reared from *Conotrachelus affinis* Boh.

The Bureau of Entomology has records of the rearing of this species from the plum curculio as follows:

Arundel, Md., July 13, 1905, 1 specimen (plum).
Arlington, Va., August 14, 1905, 1 specimen (peach)
Fort Valley, Ga., October 1, 1905, 1 specimen (Cratægus).
North East, Pa., July, 1906, several specimens.
Siloam Springs, Ark., July to August, 1908, 4 specimens (peach).
Barnesville, Ga., June 20 to September 15, 1910, 81 specimens (peach).

---

[1] Concerning the synonymy of this species, Mr. D. W. Coquillett has stated that *longipes* as a specific name for this dexidid is preoccupied by *Musca longipes* Fab. (1794), an entirely different insect from the present one, also described by Fabricius under the same name in 1805. The species, therefore, had no distinctive name in 1805, and must take the name given it by Bigot in 1884. The synonyms of ***Cholomyia inæquipes*** Bigot (1884) are *Musca longipes* Fab. (1805) (not 1794), and ***Thelairodes basalis*** Giglio-Tos (1893).

In the last instance, at Barnesville, Ga., 74 of these parasites were reared from 1,115 curculio larvæ from peaches, entering the soil August 6 to 13. The parasites from this lot emerged August 30 to September 15, the females emerging slightly later than the males on an average. In this case the percentage of parasitism by *C. inæquipes* was 6.63.

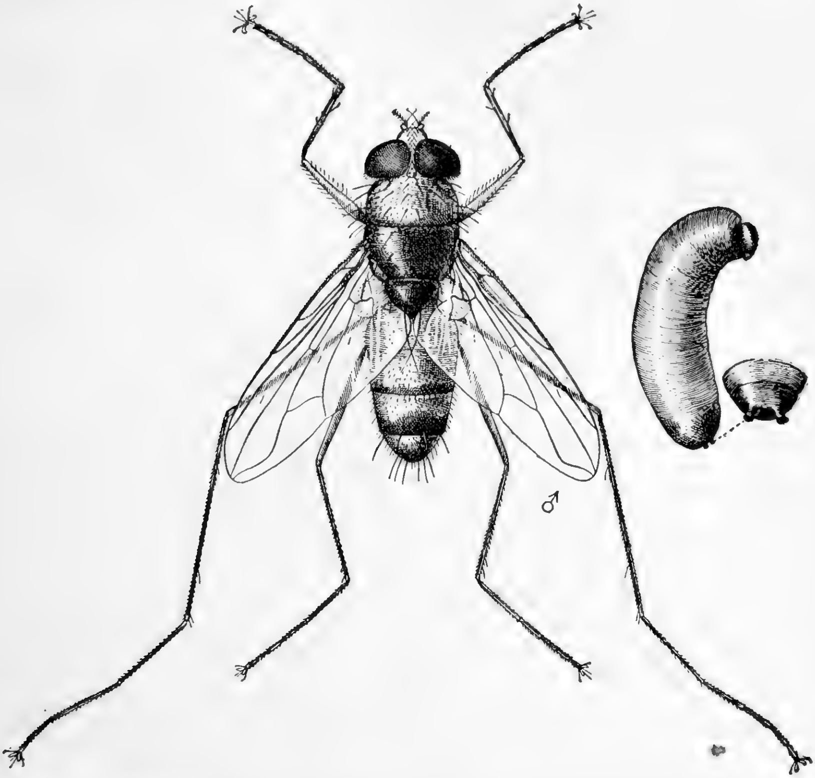


FIG. 30.—*Cholomyia inæquipes*, a fly reared abundantly from the plum curculio at Barnesville, Ga.: Adult on left, puparium in curculio larval skin on right. (Original.)

The puparium of Cholomyia (fig. 30) is formed in the soil, within the skin of the host larva, the adult parasite, on emerging, breaking through the posterior end of the old skin.

Pegomya fusciceps Zett.

This anthomyiid fly has appeared many times in jars and cages in which the plum curculio was being reared. But it is unlikely that this species is ever parasitic, and its presence may in most cases be accounted for as a feeder upon the more or less decayed fruit in company with the curculio larvæ.

PREDACEOUS INSECTS.

Several species of predatory insects are recorded as attacking the curculio, especially in the larval stage, though their importance is difficult to estimate. In our own investigations ants have been found to be efficient enemies of curculio larvæ as they are leaving the fruit and entering the soil. Numerous observations in peach orchards in Georgia show that these creatures are ever on the alert for an insect as food, and seek out and quickly destroy curculio larvæ or other soft-bodied insects. Mr. Girault, and also Mr. Rosenfeld, record frequent observations of ants attacking larvæ in the course of breeding work at Myrtle, Ga., interfering greatly with the experiments. Thus on June 16 a large number of larvæ were placed on the soil in a box for pupal records. These, however, were soon discovered by the ant, *Dorymyrmex pyramicus* Roger, which destroyed numbers of larvæ before they could be driven off. Within a quarter of an hour ants were literally swarming over the soil, in the box, and very few larvæ succeeded in getting any distance into the soil before being attacked and destroyed.

In the course of timing larvæ in entering the soil in cultivated orchards, these were often found and attacked by one or more ants (*Dorymyrmex pyramicus* Roger), usually with fatal results to the larva. Thus, a larva placed on the soil at 4.23 p. m. (May 30, 1906) was attacked eight times in succession by ants, which were repelled each time, but succeeded at the ninth attack—at 4.33 p. m. This species is especially common in Georgia orchards, and in the aggregate must exert an important influence in destruction of the curculio.

A species of thrips is recorded by Riley (2d Mo. Rept., p. 6) as very effective in destroying the eggs of the curculio.

Mr. Walsh, in an interesting article in the American Entomologist for 1868, page 33, gave observations on certain insects regarded by him as predatory on the curculio. These observations are given by Riley in his Missouri Report (p. 56), and the substance appears in Riley and Howard's well-known article on the "Plum curculio." There can be no doubt whatever as to the accuracy of Mr. Walsh's observations, but practically nothing has since been added to our knowledge of the usefulness of these insects in destroying the curculio

A larva of a species of lacewing (Chrysopa) was observed by Walsh in one side of a peach badly bored by a curculio. It was actually feeding upon a curculio larva, one-half of which had already been sucked dry. One of these insects is shown in figure 31. They are well known to feed upon various soft-bodied insects, especially plant-lice.

A carabid beetle, *Aspidoglossa subangularis* Chaud., was found inside a peach completely excavated by the curculio, from which Mr. Walsh concluded that this species also was an enemy of the curculio. These two species were regarded as undoubtedly predatory on the curculio

above ground, and the larva of a ground beetle was found by a Mr. Swing in loose earth under peach trees in large numbers, which Mr. Walsh believed searched out the insects in the ground.

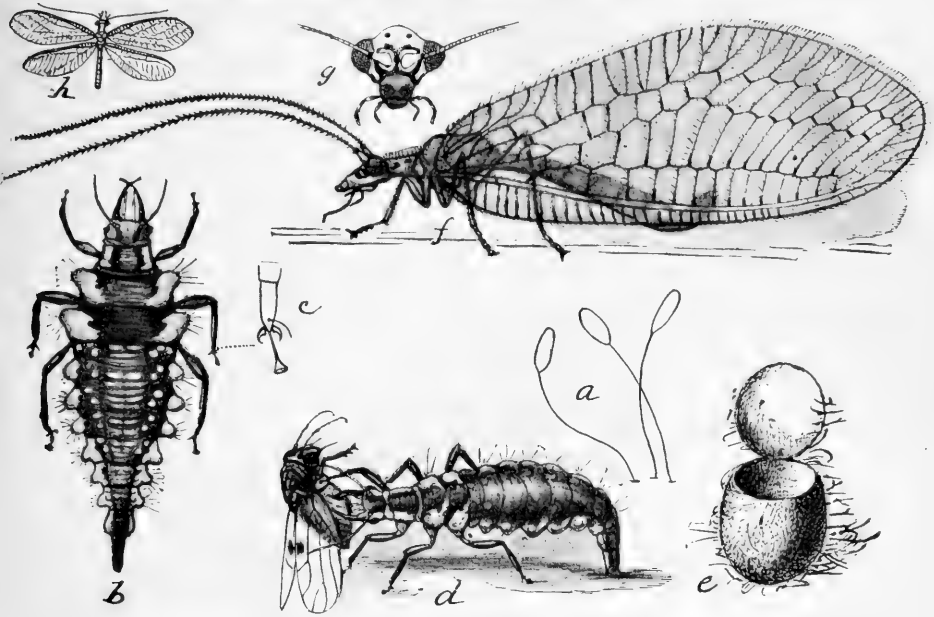


FIG. 31.— *Chrysopa oculata.* Species of Chrysopa are recorded as predaceous on the plum curculio. (From Marlatt.)

Four other species of ground beetles were found which were believed to attack the curculio grubs, although known to be general feeders, namely, *Harpalus pennsylvanicus* De Geer (fig. 32), *H. faunus* Say,

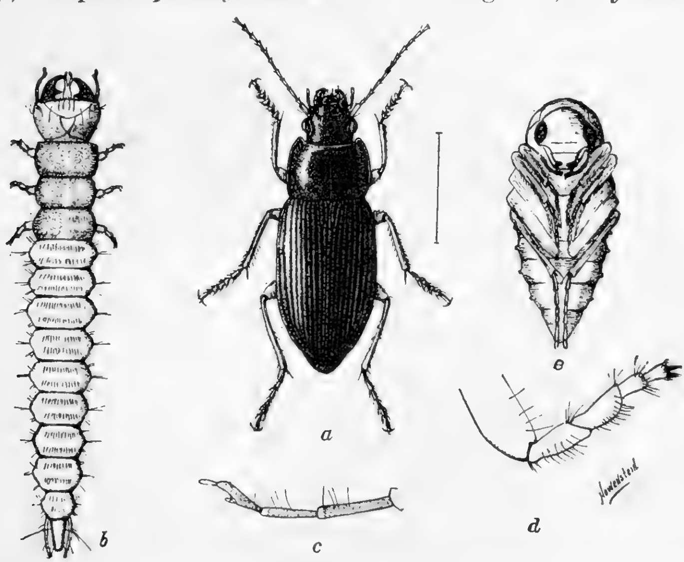


FIG 32.—*Harpalus pennsylvanicus*, a ground beetle predatory upon the plum curculio. (From Webster.)

Evarthrus orbatus Newman, and *E. obsoletus* Le Conte. The first mentioned (*H. pennsylvanicus*) was noted to be especially abundant, "absolutely swarming in all directions underground," and was thought to be the parent of the larva earlier alluded to. Walsh thus records 6 different species of insects, 2 of which fed upon the curculio, while the remaining 4 were strongly suspected of so doing. An additional species (*Chauliognathus pennsylvanicus*) (fig. 33) in the larval stage was found in curculio-injured peaches, and actually observed to feed upon the curculio grub by Mr. Swing, who forwarded the specimens to Walsh.

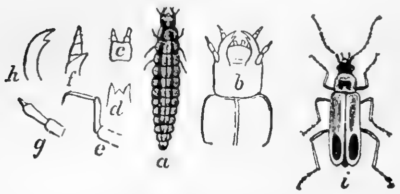


FIG. 33.—*Chauliognathus pennsylvanicus.* The larva of this beetle is recorded as a very effective enemy of the plum curculio. (After Riley.)

FOWLS AND BIRDS AS CURCULIO DESTROYERS.

The value of chickens and other fowls in checking the curculio has been alluded to by several writers, notably the older ones. There is practically no definite observation, however, to show to what extent fowls feed upon these insects. Without doubt, in orchards frequented by chickens many of the beetles and possibly the larvæ as they are leaving the fruit are found and eaten, but the good influence of fowls in this way is at most small, and confined principally to the vicinity of the house.

On the importance of birds as curculio destroyers, there are but few data. Dr. Isaac Trimble was probably first to record that the Baltimore oriole will feed upon this insect, which fact has been confirmed by subsequent observations.

The Bureau of Biological Survey of the United States Department of Agriculture has found plum curculio beetles in the stomachs of 7 species of birds, namely: Baltimore oriole (*Icterus galbula*), Windsor, Ont.; orchard oriole (*Icterus spurius*), Atlanticville, N. Y., Chester County, Pa., Marshall Hall, Md.; rose-breasted grosbeak (*Zamelodia ludoviciana*), Portland, Conn.; bank swallow (*Riparia riparia*), Sing Sing, N. Y.; yellow-throated vireo (*Lanivireo flavifrons*), Sing Sing, N. Y.; veery (*Hylocichla fuscescens*), Syracuse, N. Y.; hermit thrush (*Hylocichla g. pallasi*), Washington, D. C.

Dr. Trimble states also that he found this insect in the stomach of a toad.

REMEDIAL MEASURES.

HISTORICAL.

Measures for the control of the plum curculio have occupied the attention of fruit growers from the earliest times, and the total writings on this subject in various horticultural, farm, and other journals would comprise a very large volume. The curculio, being native, soon attacked the choice fruits planted by the pioneer settlers, and accounts of its depredations soon found their way to print. The insect was especially complained of by reason of its injuries to plums, and the culture of this fruit seems to have been attended with the greatest difficulty. Many persons, if we are to judge from the earlier accounts, gave up the fight in despair, cutting down the trees. During practically all of the last century a succession of remedies was proposed, and much discussion resulted as to their merits. Most of them were of but little if any value, and some of those proposed were actually absurd. The plan of jarring, or "shaking," as it was generally designated, is practically the only one which survived of the innumerable ones proposed. The employment of arsenicals against the curculio marked a distinct advance, though until recently their use on stone fruits had not become very general on account of injury to foliage and fruit.

As indicating the feelings of the early fruit growers toward the curculio, and their efforts to circumvent its injuries, several of the earlier accounts of the insect are inserted. These articles possess distinct historical interest, for in but few instances is it possible to follow from so early a date the gradual increase of an insect in importance as a pest, along with the increase in plantings of its host plants. The remedies proposed were legion, and about as varied as the nostrums proposed for some human ailment, as rheumatism. While no special effort has been made to list all the early remedial suggestions, the following have been noted:

Seaweed under the trees; stable manure spread under trees; thorough whitewashing of trees; air-slaked lime dusted on trees in early morning while wet with dew, after setting of fruit; fumigation with sulphur fumes; wood ashes thrown over trees during blossoming when wet with dew; sulphur and powder fired from a gun into the top of trees for a few successive mornings; sulphur, lard, and Scotch snuff mixed and rubbed on trunk and larger branches; drenching the tree with putrid soapsuds, followed by dusting with lime; flowers of sulphur sprinkled over trees after setting of fruit; sulphureted hydrogen generated from calcium sulphid; packing the earth under the trees; tobacco smudge; hanging in trees putrid flesh, as dead mice, etc., to be used by the beetles for ovipositing; burning leather

under trees on pans of charcoal; soft soap placed in crotches of limbs; burning soot under trees; paving the earth under trees with brick, slate, mortar, etc.; branches of tansy hung in trees; burning under trees woollen rags saturated with brimstone; destroying the eggs in the fruit by means of a needle-like instrument; passing around the trees a blazing straw torch, into which the beetles would fly; protecting the fruit with mosquito netting; confining in the orchard pigs, geese, poultry, etc.; fencing out the curculio with a high, 9-foot fence; fall plowing; liberal use of salt around the trees; removal of surface of soil and contained insects from around base of trees; covering soil with salt during midsummer to kill worms escaping from the fruit; picking up and destroying stung fruit; dilute sulphuric acid thrown on the soil to destroy insects in ground; bruising the tree to cause exudation of gum to prevent its development on the fruit upon which the larvæ feed; removal and destruction of black-knot disease; flooding the soil to drown insects; placing quicksilver in holes bored in trunk of trees; corrosive sublimate thrown into the soil to destroy the insects in the ground; jarring insects onto sheets held or placed under trees; asafœtida spray; whale-oil soap, sulphur, lime-and-tobacco spray; coal-tar and water spray; piles of small stones around trees; trapping curculio under chips, small boards, etc., placed on the ground under the trees; planting of nectarines as a trap crop; light traps; belts of cotton batting around the trees; lead-pipe troughs around the trees filled with oil; hanging in trees bottles of sweetened water as a bait.

The first remedial suggestions which we have seen are those in Darlington's Memorial, giving the correspondence between the early American botanist, John Bartram, and his patron, Peter Collinson. Under date of March 14, 1736–37, Peter Collinson, writing to John Bartram, refers [1] to the—

very particular account how your plums are destroyed by an insect. Pray change the stock, and graft plums and nectarines on peach stocks, which being a vigorous, free stock, and not liable to these insects, may succeed better. Pray try; I have a great opinion of its succeeding.

That the above referred to the plum curculio is evident from a later communication. John Bartram, writing under date of April 16, 1746, and speaking of the strawberry and sloe, the last of "which we have had in the country these 50 years. I plant them about my hedges, where it grows to a large size. The blossoms are prodigious full, but never one ripe fruit. They were bit by the insect, as all our stone fruit is; but the peaches, and some kinds of cherries, overgrow them." [2] In a letter under date of April 24, 1746, Peter Collinson, in writing to John Bartram, adds:

To prevent the destruction of the beetle, I confess, is not so easy as some other bad effects; yet as we know the duration of this insect is but short, if while he is so noxious,

[1] Darlington's Memorial, p. 93. [2] Darlington's Memorial, p. 175.

some contrivance could be found out to disturb or destroy him, you might then hope to taste a nectarine—one of the most delicious fruits in the universe, and much exceeds a peach, in a rich vinous-flavored juice. And an apricot is also one of the fine fruits. Last year our standards were overloaded, which were allowed to excel the wall fruit.

Suppose as soon as this beetle is discovered if the trees were to be smoked, with burning straw under them or at some distance, so as to fumigate their branches at a time the beetles are most liable to attack the fruit, or if the trees were to be squirted on with a hand engine with water in which tobacco leaves were soaked; either of these two methods, I should think, if they did not totally prevent, yet at least would secure so much of these fine fruits as would be worth the labor of people of circumstances who are curious to taste these delicious fruits in perfection.

I take it the reason the plum succeeds so well is the frequent shaking of the trees by being planted in a frequented place. The beetles are tumbled off, or else are disturbed and frightened from settling on the trees.

The earliest extended account of the insect is that by Dr. James Tilton, of Wilmington, Del., in Willich's Domestic Encyclopædia (vol. 3, p. 116), published in 1804. This original article shows a considerable familiarity with the curculio, and was much quoted by subsequent writers. Some of the methods suggested for control later came into much notoriety and use. This comparatively inaccessible article is here reproduced:

Curculio, a genus of insects belonging to the Coleoptera, or beetle order. The species are said to be very numerous. The immense damage done, by an insect of this tribe, to the fruits of this country, of which there is no similar account in Europe, has given rise to a conjecture with some naturalists, that we have a peculiar and very destructive species in America.

The manner in which the insect injures and destroys our fruits, is, by its mode of propagation * * *. Early in the spring, about the time when the fruit trees are in blossom, the Curculiones ascend in swarms from the earth, crawl up the trees, and as the several fruits advance they puncture the rind or skin, with their pointed rostra, and deposit their embryos in the wounds thus inflicted. The maggot thus imbedded in the fruit preys upon its pulp and juices, until in most instances, the fruit perishes, falls to the ground and the insect escaping from so unsafe a residence, makes a sure retreat into the earth: where, like other beetles, it remains in the form of a grub or worm, during the winter, ready to be metamorphosed into a bug or beetle, as the spring advances. Thus every tree furnishes its own enemy; for although these bugs have manifestly the capacity of flying, they appear very reluctant in the use of their wings; and perhaps never employ them but when necessity compels them to migrate. It is a fact that two trees of the same kind may stand in the nearest possible neighborhood, not to touch each other, the one have its fruit destroyed by the curculio, and the other be uninjured, merely from contingent circumstances, which prevent the insects from crawling up the one, while they are uninterrupted from climbing the other.

The curculio delights most in the smooth skinned stone fruits, such as nectarines, plums, apricots, etc., when they abound on a farm; they nevertheless attack the rough-skinned peach, the apple, pear, and quince. The instinctive sagacity of these creatures directs them especially to the fruits most adapted to their purpose. The stone fruits more certainly perish by the wounds made by these insects, so as to fall in due time to the ground, and afford an opportunity to the young maggot to hide itself in the earth. Although multitudes of seed fruits fall, yet many recover from

their wound, which heal up with deeply inflicted wounds * * *. This probably disconcerts the curculio, in its intended course to the earth. Be this as it may, certain it is, that pears are less liable to fall, and are less injured by this insect than apples. Nectarines, plums, etc., in most districts of our country, where the curculio has gained an establishment, are utterly destroyed, unless special means are employed for their preservation * * *. Cherries escape better, on account of their rapid progress to maturity and their abundant crops: the curculio can only puncture a small part of them, during the short time they hang upon the tree. These destructive insects continue their depredations from the first of May until autumn. Our fruits collectively estimated must thereby be depreciated more than half their value.

It is supposed the curculio is not only injurious above ground, but also in its retreat, below the surface of the earth, by preying on the roots of our fruit trees. We know that beetles have, in some instances, abounded in such a manner as to endanger whole forests. Our fruit trees often die from manifest injuries done to the roots by insects, and by no effect more probably than the curculio. In districts wherein the insect abounds, cherry trees and apple trees, which disconcert it most above, appear to be the special objects of its vengeance below the surface of the earth.

These are serious evils; to combat which, every scientific enquirer is loudly called upon to exert his talents; every industrious farmer to double his diligence, and all benevolent characters to contribute their mite.

Naturalists have been accustomed to destroy vicious insects, by employing their natural enemies to devour them * * *. (See BLIGHT.)

We are unacquainted with any tribe of insects able to destroy the curculio. All the domestic animals, however, if well directed, contribute to this purpose. Hogs in a special manner are qualified for the work of extermination. This voracious animal, if suffered to go at large in orchards, and among fruit trees, devours all the fruit that falls, and among others the curculiones, in the maggot state, which may be contained in them. Being thus generally destroyed in the embryo state, there will be few or no bugs to ascend from the earth in the spring, to injure the fruit. Many experienced farmers have noted the advantage of hogs running in their orchards. Mr. Bordley, in his excellent "Essays on Husbandry" takes particular notice of the great advantage of hogs in orchards; and although he attributes the advantage derived from these animals to the excellence of their manure, and their occasional rooting about the trees, his mistake in this trivial circumstance does by no means invalidate the general remarks of this acute observer. The fact is, hogs render fruits of all kinds fair and unblemished, by destroying the curculio.

The ordinary fowls of a farm yard are great devourers of beetles. Poultry in general are regarded as carnivorous in summer, and therefore cooped sometime before they are eaten. Everybody knows with what avidity ducks seize on the tumble bug (*Scarabæus carnifex*), and it is probable the curculio is regarded by all the fowls as an equally delicious morsel. Therefore, it is, that the smooth stone fruits particularly succeed much better in lanes and yards, where the poultry run without restraint than in gardens and other enclosures, where the fowls are excluded.

Even horned cattle and all sorts of stock may be made to contribute to the preservation of our valuable fruits. By running among the trees they not only trample to death multitudes of these insects; but by hardening the ground, as in lanes, it becomes very unfit to receive or admit such tender maggots as crawl from the fallen fruits. Besides, the curculio is very timid, and when frightened by the cattle rubbing against the tree or otherwise, their manner is to fold themselves up in a little ball and fall to the ground; where they may be trampled and devoured by the stock, poultry, etc. Col. T. Forest, of Germantown, having a fine plum tree near his pump, tied a rope from the tree to his pump handle, so that the tree was gently agitated every time there was occasion to pump water. The consequence was that the fruit on this tree was preserved in the greatest perfection.

All the terebinthinate substances, with camphor and some others, are said to be very offensive to insects generally. Upon this principle, General T. Robinson, of Naaman's Creek, suspends annually little bits of board, about the size of a case knife, dipped in tar, on each of his plum trees * * *. From three to five of these strips are deemed enough, according to the size of the tree. The General commences his operations about the time or sooner after the trees are in full bloom, and renews the application of the tar frequently, while the fruit hangs on the tree. To this expedient, he attributes his never failing success. Other gentlemen allege, that common turpentine would be still better; being equally pungent and more permanent in its effects. Some have sown offensive articles, such as buckwheat, celery, etc., at the root of the tree, and have thought that great advantage followed.

Ablaqueation, or digging round the trees, and making bare their roots in winter is an old expedient of gardeners for killing insects, and may answer well enough for a solitary tree, a year or two; but the curculio will soon recover from a disturbance of this sort, and stock the tree again.

There is no surer protection against the curculio than a pavement. This, however, is only applicable to a few trees. It may serve in town; but will not answer in the country * * *. (Flat stones, however, may be placed around the tree, and where lime is at hand, they may be cemented.)

Many other expedients, such as smoking, brushing, watering, etc., may be successfully employed, for the protection of a favourite tree or two; but it is manifest from the preceding history, that a right disposition of stock, especially hogs, among the fruit trees, can only be relied on by a farmer, with orchards of considerable extent. And that the stock, poultry, etc., may perform the task assigned them, it is evident, that a proper disposition of fruit trees is essentially necessary.

As the smooth stone fruits are the grand nurseries of the curculio, special care should be taken to have these effectually protected. Unless this can be done, a farmer should not suffer them to grow on his plantation. He will derive no benefit from them; and they will furnish a destructive vermin that will ruin his other fruits. Cherry trees, nectarines, plums, apricots, etc., should therefore be planted in lanes and hard beaten yards (or paved yards), the common highways of all the stock of the farm, and not beyond the range of the ordinary domestic fowls. Orchards of apple trees, pear trees, peach trees, etc., should be in one enclosure. The pear trees and peach trees may occupy corners of the whole design, so as occasionally to be fenced off. In large orchards, care should be taken that the stock of hogs is sufficient to eat up all the early fruit which fall from May until August. This precaution will be more especially necessary in large peach orchards: for, otherwise, when the hogs become cloyed with the pulp of the peach, they will let it fall out of their mouths and content themselves with the kernel, which they like better; and thus the curculio escaping from their jaws may hide under ground, until next spring. Solitary trees of one fruit or another, remote from the orchard, should be regarded as nurseries of the curculio, and ought to be cut down or removed to the common enclosure. A young orchard should not be planted in the place of, or adjacent to an old one; that it may not be immediately infested with the curculio.

It is also apparent, from what has been said, that great advantages might result from an association or combination of whole neighbourhoods against this common enemy. Although an intelligent farmer may accomplish much, by due attention, within his own territory, the total extermination of the curculio can hardly be expected, but by the concurrent efforts of whole districts.

(On this subject it may be added, that a gardener near Baltimore, who has been successful in raising plums, finds that the insect does most mischief in the night; and hence he shakes the tree every evening, and catches the insect in a sheet around it. He always burns them instantly. Wrapping each plum in a muslin bag, or in thin paper perforated with a pin, is a certain, though troublesome, mode of guarding against the attacks of these insects.)

William Bartram, an eminent naturalist of Philadelphia, in a communication to the Philadelphia Society for Promoting Agriculture, for 1807, after a description of the curculio, goes on to say:

During my travels from Pennsylvania to Florida I had sufficient opportunity to observe that the fruit trees on the sea coast and brackish water were free from the ravages of this destructive insect; this suggested to me an idea, that the saline vapors were pernicious to them, and thus I imagine that if we were to go to the trifling expense of showering our choicest fruit trees with a weak solution of common sea salt, once or twice a week, it might answer the same end of preserving the fruit; and by persevering further in a little more expense, in extending the same care to our orchards, we might in a few years expel them. But this is only a conjecture, having never made the experiment.

In the beginning of the year 1808, he added the following note:

The spring following I put the experiment on showering a plum tree on trial, with a weak solution of sea salt dissolved in water; but being too strong of salt, most of the leaves and fruit fell off on consequence of it, otherwise the experiment might have produced the desired effect, as what fruit remained was not touched by the insect, though small and disfigured by the strength of the brine; yet a few arrived to their natural size and ripened, so that I am induced to believe, that with care in tempering the solution, it will be found to be the best and cheapest remedy against the ravages and increase of those pernicious insects, yet discovered. It should be so weak as just to taste of salt.

Joseph E. Muse, writing in the American Farmer, volume 1, No. 16, page 124, under date of July 16, 1819, under the caption "Entomology," treats among other insects, the curculio, as follows:

Another insect, the curculio, of which there are nearly one hundred species, belonging also to the Coleopterous order, commands, from its universal ravages both upon the farmer and the fruiterer, the attention of every member of the community, who has it in his power to contribute, in the smallest measure, to the destruction of this ruthless foe to the wealth and luxury of man; which frustrates, by its concealed and wily movements, the most rational and well founded plans, executed by the most ardent and efficient energies of the human mind and body. Are we not inclined to exclaim, with the moral and philosophical Seneca, "*Natura quam te colimus inviti quoque.*" How repugnant to the proud feelings of man to stoop to combat with this insignificant animalcule! How resistless are the ordinances of nature, which compel us, by acts so humiliating, to admire and adore that complex creation whereby the great architect has seen fit to enforce them!

I have made experiments on the larvæ of several species of curculiones; and have found the parents so nearly similar in habitat, metamorphoses, and most other circumstances, that one description will suffice for their whole history; at least of those which I have examined; and the only mark of idiocrasy in the tribes which I have observed, consists in their choice of a *nidus;* selecting, from their peculiarities in this respect alone, the cherry, the plum, or the grain of corn, as their instinctive or innate propensities might incline them.

In a transparent bottle containing some earth, I deposited several cherries, in which were the larvæ of the curculio, that infests that fruit; in a few weeks, or rather as soon as the pulp of the fruit was consumed, which was at different periods, they retreated into the earth where upon examination some time after, I found they had assumed the state of chrysalis, which shortly resulted in that of the imago or parent; the wings of the insect were not sufficient to accomplish the flight of the insect, but merely to assist

its ascent of the body of a tree; from which circumstances, I was led to the following reflections and experiments to test their correctness:

That the remedy must be such as would act, physically, to wit: To interrupt the metamorphoses, by preventing the descent of the larvæ into the earth; to expose to the weather, the pupa, after its descent; or to intercept in its ascent of the body of the tree, the parent insect; or, chemically, by substances known to be generally deleterious to that class of animals.

The fruit being the nidus of the ovum, and the earth the habitat, in which it is brought to maturity and makes its abode, and the larva, from its soft and delicate structure, incapable of traveling, or sustaining the exposure; when the fruit containing the larva has fallen and is rotted and consumed by the insect, the larva must descend, by the most direct route, from its original depository, the fruit, into the earth, its permanent abode, there to undergo the metamorphoses, which will bring it to maturity, and fit it for a new series of depredations, which is so secretly performed, that though myriads are employed, they are never detected in executing their work of destruction, the deposit of their ova. Hence, I concluded, that one of the most effectual preventives, would be paving with brick, stone, shells, or some other hard substance, impervious to the soft larva, a circular space round the fruit tree, as extensive as the fall of the fruit, by which it would be interrupted in its descent into the earth, and consequently perish; or that it might be accomplished, by turning up the earth under the tree to the same extent, and thereby exposing to the inclemency of the weather, the tender pupa, of which two methods, the former is to be preferred; because thereby you arrest the passage of the larva to maturity, and necessarily destroy it. The latter method, if not performed in time, may allow the perfection of the imago, and in this state it is unquestionably more hardy and capable of providing another habitation, as secure and comfortable as that of its first election. And by the experiments which I have made, its descent and maturity are at uncertain and unequal periods, which would make an insuperable difficulty, in point of time, for performing the operation; if below the descent, it would necessarily be useless; if after the maturity, equally so, for reasons given.

This view of the subject has led me repeatedly to both experiments, which I have fairly and impartially made, without the influence of any prejudice, which it might be presumed, my reasoning had connected with or in favor of the former; the result was, the fruit with which I made the experiment that had been destroyed by curculiones, for many years, were in all cases, when I paved or shelled, entirely exempt; in two cases only, when the earth under the tree was turned up, at different seasons, the fruit escaped injury, but from the number that failed, I was inclined to ascribe these two to causes accidental and extrinsic.

The third method proposed, viz: to intercept the parent in its ascent of the body of the tree, by various obstacles which the mind will readily suggest, and thereby prevent its deposit of ova, though I have made no experiments upon it, I conceive to be rational, and easily accomplished; and with those species of curculiones, of which there are many, whose wings do not admit of flight, but assist them only in climbing, it would undoubtedly be effectual.

The fourth remedy which I propose, of a chemical nature, I have made but partial experiments to establish, such as are not yet satisfactory or conclusive; when finished, it will give me pleasure to report them, if the result be successful, by a fair and candid detail of facts.

The above seems to be the first definite recommendation for paving and the use of various obstacles to prevent the ascent of the trees by the supposedly wingless adults.

Also during this year (1819) the curculio was first given a scientific name by an American entomologist, Mr. W. D. Peck, from beetles reared from black-knot on cherry; the original account of which is given below:

This insect belongs to the same genus with the *Rhynchænus strobi* or white pine weevil, described in the Massachusetts Agricultural Journal for January, 1817, to a plate in which I would refer for a representation of the parts of the mouth. In that, the rostrum or snout is nearly straight; in the present species it is curved, so as to form the segment of a circle. All the thighs have two small obtuse points on the under side. In colour it is variegated with white and red hairs; the ground colour of the shelly coat on which they are placed is dark brown; The thorax is contracted behind the head; its surface is irregular, much pitted, and has a raised longitudinal line in the middle, with three small tubercles on each side of it, placed in a triangular form. The elytra are marked with longitudinal ridges and on these are placed oblong tubercles of which there are ten or twelve; four of these in the middle of the elytra are largest, smooth, and of a brown black colour. On the under side the body is pitted, or marked, with large impressed points, like the top of a thimble. The first pair of feet is rather the largest; the second the smallest, and all sprinkled with white and bright rust-coloured hairs. Figure 5 shows the natural size of the insect, and figure 6 magnified.

Mr. Pomroy was so obliging as to bring me three tumours cut from his plum-trees, later in the season, but the larvæ had left them. Being, therefore, uncertain whether the disease of the plum-trees is to be attributed to this insect or to another species of the same genus, I would call it the cherry weevil. It may be distinguished by the specific name of rhychænus (cerasi) femoribus dentatis; fulvo alboque variegatus, elytris tuberculis pluribus carinatis, quatuor in medio manoribus nigris.

Among the 272 species of this genus, mentioned by Fabricius, there were several found in Cayenne and Carolina, which are nearly allied to this; but it differs from them all, and appears to be undescribed.

The evil produced by this insect cannot be wholly remedied; but something may be done to diminish the mischief by cutting off the diseased branches. This, however, must be done at the right season, and must be the joint care of a whole neighborhood at the same time. Those which furnished the data above set down, ceased to feed on the 6th of July, rose from the earth on the 30th, and were soon ready to deposit their eggs in healthy branches; but if the diseased branches be cut off in the last half of June, a great number may be destroyed, and most effectually, by burning the amputated parts. It is possible, that in some situations they may be disclosed earlier; it will therefore be surest to prune away the diseased parts as soon as they appear, cleaning the trees now of the old tumours, that new ones may be more readily perceived.

A treatment out of the usual was that followed by a correspondent of David Landreth:

When the fruit is perfectly set or half grown, I take a small hammer and bruise the trunk of the tree in 12 or 15 places, from near the root to the branches; the sap or gum will run out which I am satisfied will prevent the fruit from falling off. My neighbor, Mr. L., has practiced the same with success. I viewed his trees a few hours ago; he is well satisfied with the utility of it.

I will not undertake to give exact reasons why it should prevent the fruit falling off at a premature age; it may be that the insects feed on the sap or gum that also there may be a superfluous quantity of sap in such trees, I will entirely leave it to those of superior judgment.

Also, the following in The Farmers' Guide (1824), page 208:

It is recommended to put a ring round the tree, of a mixture of grease, or blubber, mixed with salt. Perhaps some of the other ingredients for destroying worms, would answer a better purpose.

Again, in the New England Farmer, volume 9 (1830), is the following:

In the month of July, I visited the beautiful settlement of Mr. Rapp, at Economy, on the bank of the Ohio, 14 miles below Pittsburg, and was highly gratified to see his numerous plum and prune trees loaded with fruit, uninjured by the insect. The senior Mr. Rapp informed me that while his trees were in bloom, his gardener placed around the body of them, a few inches above the ground, two pieces of boards, of suitable size, say six inches by twelve, out of which a semi-circular portion had been cut, so that when fitted together, around the tree, they would completely invest the body. These were confined together by two narrow battens, secured with screws, on the under surface. On the upper surface, a circular channel was cut, half an inch deep, and one inch wide, so as to surround the tree. The joints between the two boards, where crossed by this channel, were closed with putty, and any vacancies between the boards and the tree carefully stopped with clay mortar. The circular channel is then fitted with tar, and presents an effectual barrier to the progress of the insects. Some attention is required, to see that the tar does not leak out or become hardened.

An article by James Thatcher, in the New England Farmer for March, 1840, is illustrative of a series of recommendations based on the believed efficacy of repellent substances, a portion of which is given:

There is another process to be recommended, in which I have great confidence, as a part of our warfare against the curculio. It is to make a direct attack upon the female beetle while she is about to puncture the fruit to engender her young brood. This may be done by throwing from a garden engine or Willis' excellent syringe, a liquid substance that will create a sort of deleterious atmosphere which will compel her to quit the tree, and will destroy the vitality of her eggs, should they have been deposited. I will name the following articles for this purpose: the composition of sulfur and lime recommended for grapes in Mr. Kendrick's Orchardist, p. 328; a strong decoction of tobacco or snuff; chloride of lime; a weak solution of potash or even soapsuds. These materials, if showered over the trees and fruit, would prove so offensive as to force the female visitor from her generating process. The most proper time for this operation is in the evening, in order to meet the enemy, whose attack is supposed to be during the course of the night. This operation should be repeated several times during the week, from May to August, and the tree should frequently receive a thorough shaking, by which the insects will be greatly disturbed and made to fall to the ground. Should my plan be deemed too onerous, the cultivator who may adopt it in full or even partially, may be assured that (in my opinion) he will have no cause to regret his labor.

Belief in the efficacy of paving is shown by the following article which appeared in the New Genesee Farmer, volume 3, page 98 (1833):

D. Longstreet says that a gage plum tree which stood over a pavement, ripened its fruit in perfection last year, while all the fruit of his other trees of that kind, which were not over pavements, was destroyed by the curculio. In order to show that the result was caused by the pavement, he says that a plum tree, standing near the path to the barn, not paved but which was frequented almost hourly, lost all its fruit. Such facts ought to be recorded and generally known.

The codling moth and curculio were for a long time confused in the minds of many fruit growers and more or less the subject of debate in the journals of the day. The following, by N. Darling, from the Cultivator, December, 1840, page 190, is illustrative of this fact:

In the September number of the Cultivator (p. 136) you say in answer to a correspondent that "the worm in the apple as well as in the plum and cherry is a species of curculio." Also, that "the worm with the fruit, falls upon the ground, in which the worm takes up its abode in the chrysalis state, until revivified and changed by the spring, it issues a perfect insect.

I am well convinced there is a mistake here, in two particulars: 1st, as to the worm in apples being a curculio; 2nd, as to the curculio continuing in the ground till spring.

In 1831, seeing it stated in all the books that the curculio, in its chrysalis state, remained in the ground during winter, I undertook to verify the fact by actual experiment. The result was communicated to the "New York Farmer" (Vol. IV, p. 178–179). But as many of your readers have probably not seen that book, you may do a service by publishing an extract from it.

I put some moist earth into a tumbler, about the first of June and placed about 20 small peaches, containing worms, upon the earth, and covered the tumbler with a piece of glass. June 30th, the worms had all left the peaches and had all crawled into the earth below. July the 7th, the worms had divested themselves of their skin, without having formed a shell or cocoon, and were nearly changed to bugs. At this time they were white, and showed upon the breast the soft rudiments of the proboscis, legs, and wings. These parts had not attained their full size, and appeared immovable. One insect, however, had completed his metamorphosis and was a perfect bug, of a mahogany color. All have since left the earth of their own accord, having finished their change, and are now (July 19th) creeping about the tumbler and feeding on a plum leaf. On the 10th of July I opened the ground under a peach tree and found the insects in great numbers from two to four inches beneath the surface, in all stages of their metamorphosis. July 19th, I found one in the earth under an apple tree, but could find none under peach trees. It appears then that this insect retreats into the earth about the first of June, where it divests itself of its skin, and changes into a bug before the 19th of July, by which time it leaves the earth. What becomes of the bug from July to May following, remains to be discovered.

The curculio is not the only insect that produces the worm in our fruits. I stated above that about twenty peaches were placed in the tumbler. In the earth under them were six small, oval cocoons, thick strong and smoothly spun, which contain worms that manifest no approach toward a change. The same cocoons are also found under peach trees. The worms in these envelopes are different from those of the curculio; they are smaller; they are white throughout;[1] while the larvæ of the curculio have orange colored heads. There is reason for the belief that the larvæ of the curculio, all or most of them, leave the various fruits in which they are deposited as early as the beginning of July, and that the worms found in fruits after that time, have a different parent. Some years ago, I preserved a worm from a Vergalieu pear, which produced a gray miller. Last November a worm from a Newton Pippin placed itself in a cavity on a board, covered itself with a web, and remained till April when it produced a gray miller like that produced from the pear.

I continued my observations during that summer, and sent another communication to the New York Farmer (Vol. IV, p. 248), from which the following is an extract:

I have said there is reason for the belief that the larvæ of the curculio, all or most of them, leave the various fruits in which they are deposited as early as the beginning of

[1] Probably (*Porizon*) *Thersilochus conotracheli* Riley, a parasite of the curculio.

July, and that the worms found in fruits after that time have a different parent. One reason for this belief is, that after that time very little fruit is left in which their eggs can be deposited, and what little is left is, for the most part, untouched by the curculio. Let me present a hasty estimate of cherries, apricots, plums, and peaches, in my orchard; on the first of May last, there were probably 200,000; on the first of July, the number remaining on the trees did not, I am confident, exceed 500. Of that 500 perhaps 20, before the middle of August contained a curculio, the rest continued fair. I think it would puzzle Dr. Tilton to say where that vast multitude of curculios that deposited 199,500 eggs before the first of July, have deposited them since that time, if they continue their ravages, and equally puzzling it must be to devise a reason why any fruit has escaped—why only 20 eggs should be deposited, and 480 peaches left undisturbed if this vast swarm of insects have continued its operations ever since the first of July. It may be said that they resort to apples and pears. But before the first of July the greater part of the apples had also disappeared from the trees; most of those remaining have continued since untouched by the curculio. The worms found in them are not the larvæ of that insect. I have not succeeded in finding a curculio in a pear at any time. The only worms that I have found in pears, (and I have taken pains to collect a considerable number this summer), are the larvæ (I believe) of the gray miller mentioned in my former communication. They resemble the larvæ of the curculio in having orange colored heads, but differ from them by being larger, and having a slight tinge of scarlet or brick color upon portions of the body. Instead of popping into the ground, they crawl under the rough bark of the trees, inclose themselves in a web, and are transformed into a chestnut colored chrysalis. Placed in a tumbler with moist earth, they form a web upon the cover of the tumbler, and there undergo their change. As none have yet left the chrysalis state, I suppose (as was the case with those which I have before preserved) that they do not complete their metamorphosis till spring. All the worms found by me in apples, since the first of July, have been *similar* to those in the pear.

An excellent observer, David Thomas of Cayuga, maintained the prevailing opinion in regard to the worms in our fruits, and with a view to show that I was incorrect, he took "a worm with an orange colored head, from a Bell pear and put it in a tumbler, with moist earth," on the fifth of August. On the eighth of August he took from apples "three more worms with orange colored heads, and which appear to be the full grown larvæ of the curculio—another similar, but only half as long—and two others resembling the former with brown heads, but 100 (10?) times less in bulk than the first kind. Viewing these last under the microscope, I am satisfied that they also are larvæ of the common curculio, thus far confirming Dr. Tilton's remark that this insect continues its ravages from May until autumn." (New York Farmer, Vol. IV, p. 205.)

In a subsequent communication, in October, with his accustomed candor, he says, "N. Darling may be interested to learn that the worms which I confined 'with orange colored heads,' left the moist earth, and encased themselves in a web under the cover of the tumbler. Soon after one of them came forth a dark gray miller; and I conclude there was no curculio among them. We are therefore indebted to him for the interesting discovery that the larvæ of several insects feed on our fruits; and it is now rendered at least probable that Dr. Tilton ascribed too much of this mischief to the curculio." (New York Farmer, Vol. IV, p. 281.)

With these facts before us I think we may safely conclude that the worm in apples is a larva of a gray miller, and not of the curculio, which is a bug. Also that the curculio leaves the ground in a short time after entering it. Its winter retreat has not, within my knowledge, yet been discovered.

If your correspondent will look under the rough bark of his apple trees in October, he will find a great many of the worms from this fruit, which have shut themselves in with a web, and are transformed into a chestnut colored chrysalis. If he will care-

fully preserve them, he will find them coming out a gray miller. By simply scratching off, or rather picking off this rough bark (the scales or flakes, I mean) a vast multitude of these insects may be destroyed—not all, however, for they resort to other places of concealment, such as crevices in boards, posts and rails.

That the curculio could be fenced out was the belief of some; note the experience of W. Manice from the Cultivator, of 1854, p. 157:

W. Manice, of Long Island, constructed many years ago a tight board fence around his plum orchard, about nine feet high, with tight board gates. The curculio did not fly high enough to enter, many striking the sides of the fence and falling outside. An acquaintance when in full fruit informed us that all the trees within the enclosure were heavily loaded with plums at the same time he observed a tree outside that had lost every specimen.

The following is interesting as indicating the prevalent opinions of fruit growers as to remedies by the middle of the last century:

At the regular monthly meeting of the St. Louis Horticultural Society, held on the 7th of May, 1849, the curculio was the subject of some interesting remarks; an abstract of which we publish from the minutes. We hope the worthy president will persevere in his experiments until he shall have discovered a specific for this most serious hinderance to the cultivation of fruit.

The president stated that his attention had been called to the various recommendations of remedies or preventives of the ravages of the curculio, one of the most nefarious pests of the orchard in that part of the country. This insect invariably takes our entire crop of apricots, nectarines, and plums, and injures the cherries, and even peaches. He has determined to try every practicable proposed remedy of which he could avail himself the present season. The following were among those suggested:

1. Horse stable manure. This was believed to be ineffectual.

2. Spreading sheets under the trees, and tapping the body and branches with a mallet, the insects will fall into the sheets, and may be caught and killed. This is believed to be perfectly effectual, though laborious practice: it must be pursued every morning for two or three weeks from the time the trees cast their flowers. He presented a vial containing sixty-one of these insects, which he caught from three apricot trees on the morning of the 5th of April, the young apricots being nearly the size of peas.

3. Placing a lighted candle under the tree, for two or three hours in the evening in a tub or box whitewashed inside, and having at the bottom an inch or two of water.

4. Placing old iron hoops, or pieces of iron, in the branches of the tree. He had seen at his mother's residence, last fall, a green gage tree having an iron hoop entwined among its branches, and from which a crop of fruit was always obtained whilst the fruit of other plum trees near by, without the iron, was destroyed. Dr. S—— had mentioned to him facts in connection with the subject, which led him to infer that some potent effect was attributable to the iron; it may be worthy of a trial.

5. The insects may be fenced out by a tight board fence eight to ten feet high. A gentleman on Long Island succeeds perfectly with his, but he also paves the ground and plants his trees in dwarf, six feet apart.

6. Placing a coat of salt under the trees. This is believed to be ineffectual, as he had partly tried it, but without success.

7. Covering the ground under the trees with clay. This he had tried, and it did no good.

8. Hanging bottles of sweetened water in the trees.

9. Smoking the trees with the fumes of burnt sulfur.

10. Washing the trees, and even the fruit with the strongest decoction of tobacco and whale oil soap suds will have no effect.

11. Swine and poultry, running daily among the trees, during the fruit season, as a permanent annual practice, will ultimately drive away or destroy the insect. The poultry, however, are not alone sufficient. Swine are the best exterminators, by destroying the larvæ of the insect in the fruit as it falls. The insect will avoid places unfavorable to the entrance of its young into the ground.

Captain Bissell said he had tried horse manure and salt without any effect. He was inclined to try the swine.

General Milburn said that a Mr. Price, of this county, kept off the insects by tying a band of sheep's wool around his plum trees.

Mr. Turner said that a withe around the tree, kept moist with tar, had proved ineffectual with him.

Mr. Clark said that the insect would not attack the fruit upon a tree standing in a frequented walk.

The foregoing will indicate the general trend of the early remedial suggestions. In the literature on the subject there is much testimony in favor of pasturing orchards with hogs and sheep, and allowing fowls to run in them, and of paving under the trees. Jarring, although recommended and practiced to a certain extent by 1830, apparently did not come into general use until considerably later. The development of this method forms an interesting chapter in the evolution of remedies for the curculio, but may be considered only briefly (p. 168).

PREMIUMS FOR REMEDIES FOR THE CURCULIO.

Premiums have often been offered for the discovery of a suitable method of control of an injurious insect, and the plum curculio is no exception. The amounts of the awards, however, actually offered were small as compared with the amounts offered for other species, notably the cotton boll weevil, for which a premium of $50,000 was offered by the State of Texas. The first suggestion for an award for a remedy for the control of the curculio seems to have been made about 1830. At this time a lady of New Jersey started a movement to raise $2,000 by subscription, and the matter was considered by the Pennsylvania, the New York, and the Massachusetts Horticultural Societies, the last organization at least recommending that $200 be appropriated by the society for this purpose.[1] The same society, in 1842, offered a premium of $100 for a successful remedy for the curculio, which amount was raised to $200 by additional subscriptions. There were several contestants for this latter premium, though no method of control presented particularly warranted the giving of the award. A paper highly commended and published in the proceedings of the society for 1843 was prepared in this connection by Dr. Joel Burnett.

As stated in the Genesee Farmer for 1856 (p. 192) a reward of $500 was offered by the Kentucky Horticultural Society for an effectual remedy which would not be so costly and troublesome as to prevent its general employment.

[1] History Massachusetts Horticultural Society, p. 257.

Ten years later (1865) a gentleman from Philadelphia, writing in the Country Gentleman (p. 270), suggested a reward of $50,000 for a method of curculio control, though no action appears to have resulted from his suggestion.

A somewhat different plan of securing the subjugation of the curculio was adopted by the Fruit Growers' Association of Ontario. In their list of prizes for 1870 (p. 72) is the following:

> To any person sending to William Saunders, esq., London, transportation prepaid, 2,000 plum curculio (*Conotrachelus nenuphar*), the sum of $25, or sending 1,000 the sum of $10, or sending 500 the sum of $5.

As a result of this offer numerous fruit growers made sendings of plum curculio during the year, the total reaching 13,653, the largest number being sent in by any one person being 2,280, jarred from 20 plum trees, 10 English cherry, and 30 peach trees, obtained for the most part from the plum trees.

The year following a reward was again offered, but the amount to be paid reduced. Thus, for 5,000 curculio, $20; for 3,000, $10; and for 2,000, $5. As stated in Mr. Saunders's report to the association for 1871, the number of beetles received was notably less than during the year previous, supposedly on account of the reduction in price, no award being made for a less number than 2,000 beetles.

THE RANSOM CHIP PROCESS.

Considerable interest was aroused in the so-called Ransom chip process proposed by W. B. Ransom, of St. Joseph, Mich., in 1870, the discovery of which was announced in an extra of the St. Joseph Herald. The proposed method is reviewed at length in the American Entomologist for June, 1870 (p. 225), by Dr. Riley, who points out that the process had been previously proposed by Mrs. H. Wier, of Johnsonville, N. Y., in the Rural New Yorker of January 28, 1865. The plan consisted in first taking from under the trees all trash, clearing and packing the soil for a couple of feet around the collar of the tree and, second, in placing pieces of bark, chips, small stones, etc., close to the trunk of the tree, for hiding places for the beetles, from which they were to be regularly collected and destroyed.

The method was compared with jarring by Dr. E. S. Hull [1] during the period May 29 to June 2, with the result that by the chip process 13 beetles were taken (including 7 apple curculio), whereas by jarring 309 were captured.

JARRING FOR THE CURCULIO.

Jarring, or shaking, as the practice is very generally designated in the earlier literature, was recommended at a very early date. Its value rests upon the habit which the beetles have of folding their legs and falling to the ground when disturbed.

---

[1] Trans. Ill. Hort. Soc., 1870, p. 228.

A suggestion as to the worth of the practice is found in the Bartram-Collinson correspondence in 1746 (p. 157). Jarring was more or less in vogue at the beginning of the last century. In Dr. Tilton's article, published in 1804 (p. 157), he refers to the successful experience in jarring of a gentleman living near Baltimore. He also records results obtained by Col. T. Forest, of Germantown, who, having a fine plum tree near his pump, tied a rope from the tree to the pump handle so that the tree was gently agitated every time there was occasion to pump water. The consequence was that the fruit on this tree was preserved in the greatest perfection.

The habit of the curculio to fall to the ground or to play possum when disturbed is commented on in the American Farmer for July 17, 1829, namely:

When the branch on which it is at work is shaken with some little violence, it drops to the earth but makes no attempt to hide. It immediately contracts itself into a small lump very much resembling a grain of small black gravel, and thus it evades generally the closest inspection.

Mr. David Thomas was perhaps one of the first fruit growers to exploit the method of jarring, and he occasionally published accounts of his success, which doubtless greatly hastened its more general use. Writing in the New England Farmer for 1831 (p. 413), he says:

We have lately discovered that much fruit has been punctured by the curculio, and we have found it necessary to resort to the method which I proposed in the New York Farmer, Vol. III, No. 3. By spreading sheets and jarring the trees we have destroyed more than 300 of these insects within the last 24 hours, and have only to regret that this work has been so long delayed.

Further along in the article he adds:

Before closing this comment I wish to express my entire confidence in the method which we now employ for destroying this insect; and again recommend it to those whose fruit trees stand in inclosures from which geese and pigs must necessarily be excluded. Diligent attention to this business night and morning for a short period, though it may not destroy the whole colony, will secure a sufficiency of fruit, and we ought to remember that the labors of next year may be greatly lessened by gathering and destroying in the present season the damaged fruit as it falls.

An improvement in the method of dislodging the beetles was hit upon a year later, as described by Mr. Thomas in the Genesee Farmer for 1832 (p. 185). He states:

Not three days ago I saw that many plums were punctured and began to suspect that shaking the trees was not sufficient. Under a tree in the remote part of the fruit garden, having spread the sheets, I therefore made the following experiment: On shaking it well I caught 5 curculios; on jarring it with the hand I caught 12 more; and on striking it with a stone 8 more dropped on the sheets. I was now convinced that I had been in an error, and calling in the necessary assistance and using a hammer to jar the tree violently, we caught within less than one hour more than 260 of these insects

The following spring Mr. Thomas again refers to his method of catching the curculio (Genesee Farmer, 1832, pp. 155–156), and describes shaking the trees and catching the beetles on sheets kept exclusively for the purpose, as commonly practiced. It would thus seem that jarring was rather generally employed in his neighborhood at that time.

In 1833 the discovery was made that it was advantageous to strike the sawed-off butt of a limb as follows:

This spring I sawed off one or more lateral branches of about an inch in diameter from each tree, leaving a stump to project, from which I removed the bark that the wood might harden and also made the head convex with a knife to prevent it from battering under the mallet.

There are frequent accounts in subsequent literature dealing with the methods of jarring and giving instructions for the preparation of sheets (see fig. 34), but the practice seems to have become notably general by about 1850. The umbrella type of catcher came into use apparently somewhat before 1848. In The Cultivator for that year (p. 182) is given a short account of an umbrella catcher which, it was stated, had been employed for some years. Numerous forms of catchers were described and some of them illustrated, but all were essentially of the sheet type, to be held or placed on the ground under the tree, or in the form of an inverted umbrella.

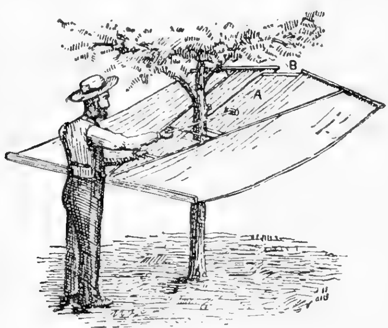


Fig. 34.—A simple form of curculio catcher for use by one person. (After Popular Gardening.)

An interesting résumé of Mr. Thomas's experience after more than 20 years was given by him in The Cultivator for August, 1851 (p. 269), in which he expressed fullest confidence in the method and stated that whenever the work had been thoroughly done he had never been disappointed in results.

Mr. James Mathews, writing in the Country Gentleman, February 17, 1853 (p. 102), speaks of having employed the jarring system for many years. He employed the umbrella type of catcher.

A much more pretentious curculio catcher was devised by Dr. E. S. Hull, of Alton, Ill., a description of which was given in the Practical Entomologist for April, 1867, and also in the Iowa Homestead, a reduced illustration of which is shown in figure 35. A patent was later taken on this catcher by Dr. Hull, but as it proved cumbersome several modifications were quickly developed, and some of them by Dr. Hull himself. A machine which Dr. Riley considered an im-

provement over that of Dr. Hull was described in his Third Missouri Report, page 20. Dr. Riley stated that this machine, which had been devised by Mr. L. M. Ward, was in quite general use around St. Joseph and Benton Harbor, Mich.

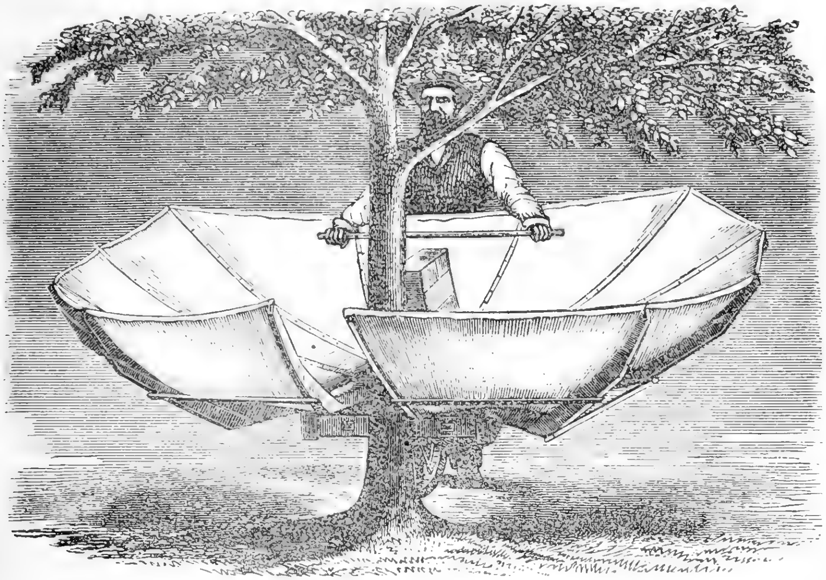


FIG. 35.—A cumbersome wheelbarrow type of curculio catcher, developed and patented about 1869. (After American Entomologist.)

Another curculio catcher, devised and patented by Dr. M. M. Holton, of Centralia, Ill., is also described by Riley. All of these devices indicate an increase in the practice of jarring and the general demand for apparatus for this purpose.

FIG. 36.—A light wheelbarrow curculio catcher, for sale as late as 1905.

At the present time there are perhaps few if any individuals or firms offering curculio catchers for sale, although unquestionably a considerable number are still in use. A form of catcher which was on the market in 1905 is shown in figure 36, and has been much used in

western New York. According to the manufacturer, the umbrella was made in sizes of 8, 10, and 12 feet, costing from $15 to $16.50, according to size.

Many growers who have jarred for this insect, and especially where labor has been abundant, have preferred to use sheets on frames. Extensive work has until recently been in progress in the orchards of the Hale Georgia Orchard Co. and elsewhere in the South. The sheets and mode of use are shown in Plate XIV, figure 2.

PRESENT STATUS OF JARRING.

The last few years have witnessed a notable increase in spraying for the curculio, with a corresponding decrease in jarring. This old remedy will doubtless more and more fall into disuse with the increase in spraying operations.

One of the largest jarring operations recorded is that by Messrs. W. M. Scott and W. F. Fiske.[1] During 1900 a Georgia orchardist jarred 200,000 bearing peach and 50,000 bearing plum trees about six times during the period from April 18 to June 1. Eleven gangs, or 55 hands, were engaged in the work, at a total cost of about $1,000. It was estimated that about 137,000 curculios were caught during the season. Curculio damage in this orchard was placed at about 4 per cent of the crop, as compared with an estimate of about 40 per cent injury in an adjacent orchard of 130,000 trees.

Although jarring had so long been in use, and was so generally recommended, there are practically no precise data in literature indicating just what degree of protection is afforded, nor any relative to its value as compared with its cost.

During 1906, at Myrtle, Ga., an attempt was made to secure data on the value of this work on peaches. A block of 1,000 6-year-old Elberta trees was selected from a larger block of 10,000 trees and jarred every other morning from April 11 to June 9. Twelve trees in the jarred block were used for making examinations of the fruit throughout the season and an identical number were used in the larger, unjarred block of the same variety. The results are shown in Table LXXXVI:

[1] Bul. 31, n. s., Bur. Ent., U. S. Dept. Agr., pp. 24-35, 1902.

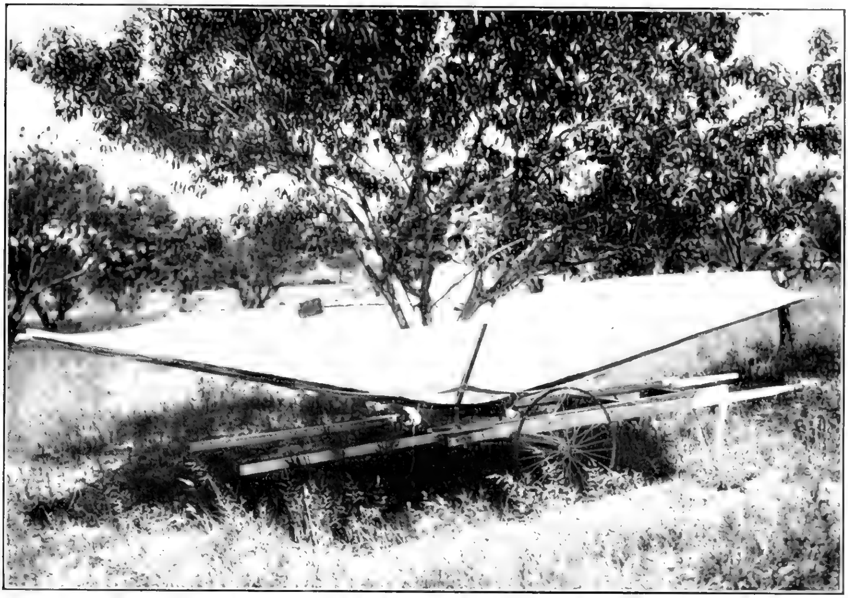


FIG. 1.—A WHEELBARROW CURCULIO CATCHER, USED IN NEW YORK STATE.

FIG. 2.—CURCULIO CATCHER MADE BY SHEETS ON FRAMES, IN USE A FEW YEARS AGO IN GEORGIA.

JARRING APPARATUS IN USE OR RECENTLY IN USE AGAINST THE PLUM CURCULIO.

TABLE LXXXVI.—*Results of jarring Elberta peaches for the plum curculio, Myrtle, Ga., 1906.*

Plat No.	Treatment.	Tree No.	Fruit from ground.		Fruit from tree.		Total number of fruits.	Total number of fruits infested.	Average percentage sound fruit.
			Total number.	Total number infested.	Total number.	Total number infested.			
I	Jarred	1	75	24	79	2	154	26	....
		2	43	29	58	6	101	35	....
		3	56	7	96	4	152	11	....
		4	72	29	157	25	229	54	....
		5	43	10	192	10	235	20	....
		6	113	20	310	12	423	32	....
		7	35	12	120	3	155	15	....
		8	96	19	345	15	441	34	....
		9	43	12	270	17	313	29	....
		10	19	2	99	7	118	9	....
		11	24	7	47	3	71	10	....
		12	6	1	30	5	36	6	....
			625	172	1,803	109	2,428	281	88.42
II	Untreated	1	188	45	356	38	544	83	....
		2	35	6	138	9	173	15	....
		3	61	14	99	7	160	21	....
		4	71	22	195	17	266	39	....
		5	14	6	44	3	58	9	....
		6	21	17	123	14	144	31	....
		7	30	9	129	13	159	22	....
		8	36	11	192	11	228	22	....
		9	8	5	29	1	37	6	....
		10	32	8	175	5	207	13	....
		11	20	4	95	9	115	13	....
		12	27	6	105	8	132	14	....
			543	153	1,680	135	2,223	288	87.04

As will be noted, the jarred plat gave 88.42 per cent of fruit free from infestation, as against 87.04 per cent on the untreated block, a difference in favor of the jarred plat of 1.38 per cent. Only 2,606 beetles were captured during the season, and the comparative scarcity of these doubtless explains why there was practically no difference between the two blocks.

Table LXXXVII gives results of jarring peaches at Siloam Springs, Ark., during 1908. A block of 950 Elbertas was jarred from March 28 to June 27. Nine trees from the jarred block and a like number from an adjacent untreated part of the orchard were used for making counts, as detailed in the following table.

Table LXXXVII.—*Results of jarring Elberta peaches for the plum curculio, Siloam Springs, Ark., 1908.*

Plat No.	Treatment.	Tree No.	Fruit from ground.		Fruit from tree.		Fruit knocked off in jarring.		Total number of fruits.	Total number of fruits infested.	Average percentage of sound fruit.
			Total number.	Total number infested.	Total number.	Total number infested.	Total number.	Total number infested.			
I	Jarred	1	815	14	47	18	309	1	1,171	33	....
		2	520	3	45	13	165	1	730	17	....
		3	498	8	31	10	110	0	639	18	....
		4	469	26	22	7	92	0	583	33	....
		5	326	5	26	7	87	1	439	13	....
		6	512	6	19	7	183	0	714	13	....
		7	705	15	83	25	267	0	1,055	40	....
		8	679	12	31	11	211	1	921	24	....
		9	461	8	33	8	182	0	676	16	....
			4,985	97	337	106	1,606	4	6,928	207	97.01
II	Untreated	1	324	28	32	17	....	....	356	45	....
		2	352	29	29	13	....	....	381	42	....
		3	341	23	25	11	....	....	366	34	....
		4	513	39	49	24	....	....	562	63	....
		5	458	22	34	15	....	....	492	37	....
		6	598	35	42	19	....	....	640	54	....
		7	243	32	37	17	....	....	280	49	....
		8	480	22	40	12	....	....	520	34	....
		9	414	22	41	13	....	....	455	35	....
			3,723	252	329	141	....	....	4,052	393	90.30

The spring of 1908 in that locality was cold and the beetles, which were not numerous, were much retarded in their movements. A total of 2,189 curculios was taken during the season. The jarred block shows a gain of only 6.71 per cent of sound fruit over the block not jarred.

Also, at Barnesville, Ga., during 1910, a block of 336 trees in 10 rows was jarred from March 10 to time of picking fruit (and subsequently for other records). A check plat of 60 trees (10 rows of 6 trees each) was laid off on one end of the jarred block. Counts of fruit for infestation were made on 20 trees of each plat, as shown in Table LXXXVIII. A total of 6,994 beetles was captured by July 30, when all fruit had been gathered.

TABLE LXXXVIII.—*Results of jarring Elberta peaches for the plum curculio, Barnesville, Ga., 1910.*

Plat No.	Treatment.	Tree No.	Total number of fruit.	Total number of fruit infested.	Average percentage of sound fruit.	Plat No.	Treatment.	Tree No.	Total number of fruit.	Total number of fruit infested.	Average percentage of sound fruit.
		1	857	48	....			1	961	286	....
		2	1,845	80	....			2	1,890	299	....
		3	1,286	115	....			3	1,123	137	....
		4	1,076	168	....			4	1,238	147	....
		5	606	19	....			5	364	46	....
		6	529	12	....			6	491	95	....
		7	615	7	....			7	410	48	....
		8	547	2	....			8	675	49	....
		9	434	1	....			9	470	48	....
1....	Jarred.......	10	439	0	....	II...	Untreated...	10	637	54	....
		11	295	3	....			11	184	18	....
		12	159	4	....			12	726	59	....
		13	480	13	....			13	421	65	....
		14	355	8	....			14	706	80	....
		15	519	2	....			15	398	79	....
		16	486	8	....			16	256	42	....
		17	478	9	....			17	424	61	....
		18	262	6	....			18	178	64	....
		19	413	13	....			19	633	57	....
		20	112	4	....			20	368	35	....
			11,793	522	95.57				12,553	1,769	85.91

Comparing the amount of uninfested fruit from the two plats, there is shown a gain in favor of jarring of 9.66 per cent of the crop, an amount quite insufficient to compensate for the cost of the work.

During 1909 Mr. W. W. Chase,[1] of the Georgia State Board of Entomology, following a plan outlined by the Bureau of Entomology, jarred a block of 1,200 Elberta peach trees. The work of jarring, although carried out irregularly on account of scarcity of suitable labor, nevertheless gave results of interest. The block of trees used was 40 by 30 rows and paralleled a piece of woods, being separated only by a farm road. Rows were numbered from 1 to 30, beginning with the one parallel to the woods. In the jarred block, 10 trees were selected for making examinations of all of the fruit and 8 trees were selected from a nearby section of the orchard, untreated.

As stated in the table, a total of 4,338 peaches was examined from the 10 jarred trees, of which 1,739 were infested, giving a percentage of sound fruit of 59.91. From the unjarred block of 8 trees a total of 2,515 fruits was taken, 1,664 being infested, giving a percentage of sound fruit of 33.84, a difference in favor of jarring of 26.07 per cent.[2]

[1] Bul. 32, Ga. State Bd. Entomology, p. 29, 1910.

[2] In the publication cited an error in computation manifestly exists where a benefit of 6 per cent is stated in text, though a loss of 6 per cent is given in the table, while a correct computation from the numbers given of infested and uninfested fruit shows a benefit of 26 per cent.

Considering the several records of jarring on peach given above, it would appear that this practice, on the whole, is not warranted from the benefits derived. Notwithstanding the large total of beetles caught in the course of the Barnesville experiment, averaging 20.81 per tree, there was a lessening of infestation of only about 10 per cent, as compared with the check. In the other instances, where the insects were less abundant, the difference is inconsequential.

It is, however, a firmly established belief that jarring has been of the greatest value in protecting the plum crop, though no exact data have been given, and the inference possibly follows the fact of capture of the beetles in considerable numbers. It is regretted that there has been no opportunity to try jarring on plums. In jarring for peaches, furthermore, quite a number of the fruit is almost unavoidably knocked off, a considerable proportion of which is sound. When there is an abundance or excess of fruit, this is beneficial; but when the crop is light, there is an important loss of fruit. In the Siloam Springs work, in 1908, a total of 1,610 peaches was knocked off during the season from the 9 trees, of which 4 only were infested.

CULTIVATION FOR DESTRUCTION OF PUPÆ.

As has been shown elsewhere (p. 87), practically all of the larvæ of the plum curculio pupate less than 3 inches below the surface of the soil. Over 92 per cent pupate within 2 inches and 63 per cent within 1 inch of the surface of the ground. The pupæ of the curculio, in common with those of many other insects, are extremely tender and are readily killed or injured by disturbance of the soil. It is probable that the mere breaking of the pupal cell, leaving the earth in contact with the body of the pupa, would be fatal to many, while others are undoubtedly killed by the crushing action of the earth. Superficial tillage of orchards when the pupæ are in the ground in maximum numbers should therefore serve greatly to reduce their number for the following season, and tillage during this season is extremely desirable as a part of proper orchard management. Pupæ not actually killed are exposed to the elements and are subject to the attacks of predaceous enemies, as ants, bird, etc. Sunlight appears to be quickly fatal to them and, as stated by Crandall, exposure to the air on a warm day in the shade will result in their death in a few hours. Extended observations on the life history of the curculio from various localities (p. 64) indicate that the insect is in the pupal condition in the ground for any locality in from 50 to 65 days after the falling of the blossoms of such fruit as the peach and plum. Data have also been presented to show that the minimum time spent in the ground is about 20 days, though the actual period of pupation is less.

Shallow cultivation should begin therefore in about 9 weeks after blossoming of peach. These cultivations should be frequent, that is, every week or oftener if practicable, and continued for 6 or 7 weeks. As most of the larvæ enter the soil near the deserted fruit, the earth under the spread of the limbs of the trees will contain the great majority of the pupæ and should receive special attention in the course of the cultivations.

Some experiments have been made to determine the effect, on pupæ, of disturbing the soil. Boxes containing soil were kept in a way to approximate out-of-doors conditions as nearly as possible. In some boxes the soil was stirred, and in others left undisturbed for comparison. While it has been impossible exactly to duplicate the disturbance of the earth that would result from field cultivations, yet the results are in a way comparable, and indicate as definitely, perhaps, as may be determined what may be expected from work of this character. The essential features of the results are shown in Table LXXXIX.

In the work at North East, Pa., the boxes were sunk in the soil beneath peach trees so that the top would be about level with the surface, and were thus subjected to practically normal conditions. As indicated in the table, the soil in two boxes was disturbed with a rake on July 11 and 20, while two other boxes were left undisturbed.

In the experiments at Siloam Springs, Ark., in 1908, boxes 2 feet square without bottoms were sunk practically level with the earth under the shade of an apple tree. One box was cultivated with a hoe June 23.

In the tests in the insectary at Washington, D. C., in 1908, 4 lots were used, 2 being treated and 2 untreated. The larvæ were placed in boxes 24 by 10 inches and 8 to 10 inches deep. These were sunk almost level with the surface of the earth. Lot No. 1 was cultivated by means of a hoe July 8 and 15, while lot No. 2 was cultivated only once, on July 15. The soil was disturbed to a depth of 6 inches, exposing many of the pupæ.

At Douglas, Mich., the boxes were placed in a bright though somewhat shaded location and the soil in lot No. 1 was disturbed weekly by means of a small stick or lead pencil drawn back and forth, extending to a depth of 3 or 4 inches in the soil.

In the experiments at Barnesville, Ga., in 1910, 4 bottomless wooden boxes 10 by 12 by 8 inches were used and sunk in the soil on the north side of a house, thus being shaded for about one-half of the day. Lots Nos. 1 and 3 were placed in sandy loam and lots Nos. 2 and 4 in red clay.

TABLE LXXXIX.—*Effect of stirring soil on destruction of pupæ of the plum curculio.*

Locality and date.	Lot No.	Number of larvæ used.	Treatment given soil.	Adults emerging.	Percentage of adults from larvæ.	Average percentage adults from treated boxes.	Average percentage adults from untreated boxes.	Percentage gain from treatment.
1906.								
North East, Pa	1	200	Soil disturbed July 11 and 20.	25	12.50			
Do	2	200	do	32	16.00	14.25		
Do	3	200	Soil not disturbed	71	35.50			
Do	4	200	do	75	37.50		36.50	22.25
1908.								
Siloam Springs, Ark	1	451	Soil disturbed June 23	60	13.30	13.30		
Do	2	451	Soil not disturbed	135	29.93		29.93	16.63
Washington, D. C	1	558	Soil disturbed July 8 and 15.	20	3.58			
Do	2	51	Soil disturbed July 15	24	47.06	7.22		
Do	3	468	Soil not disturbed	267	57.05			
Do	4	137	do	59	43.07		53.88	46.66
1910.								
Douglas, Mich	1	98	Soil disturbed frequently.	2	2.04	2.04		
Do	2	98	Soil not disturbed	17	17.35		17.35	15.31
Barnesville, Ga	1	173	Soil disturbed June 17	21	12.14			
Do	2	191	Soil disturbed June 8	12	6.28	9.06		
Do	3	173	Soil not disturbed	119	68.79			
Do	4	191	do	98	51.31		59.61	50.55
Average of total						10.20	43.85	33.65

As will be noted, there is with one exception an important decrease in the number of adult curculios emerging from boxes in which the earth was stirred. In the case of lot No. 2, at Washington, D. C., an unusually large number of adults emerged. The larvæ were placed in this box June 29 and were doubtless all in the pupal stage by July 15, when the cultivation was given. It is to be noted, however, that there is a considerable variation in the percentage of insects killed by stirring the soil from the different localities. This perhaps results from differences in the methods of treatment. The total average percentage of adults emerging from the treated boxes, namely, 10.20, as compared with the total average from all untreated boxes, namely, 43.85, shows a difference in favor of stirring the soil of 33.65 per cent. Comparing the total number of beetles emerging from the untreated boxes, 841, with the total number of beetles from the treated, 196, shows a probable number killed by treatment of 645, a percentage of benefit of 76.75.

SPRAYING WITH ARSENICALS.

It is impossible to state with certainty who first used arsenical poisons for the control of the plum curculio. They doubtless came in along with the use of Paris green against cankerworms and the codling moth. Paris green was recommended by Mr. G. M. Smith,

of Berlin, Wis., to the St. Joseph, Mich., Horticultural Society in the fall of 1870,[1] in the article which follows, which is the earliest recommendation we have seen:

My method of destroying the little Turk is to give the trees a judicious sprinkling of Paris green. My plum trees are living witnesses of the excellence of this treatment, for they are for the first time loaded with fruit and some of them overloaded, and not a mark of the curculio can be found. This is the third season in this region that we have used the Paris green for destroying the Colorado potato beetle, and I find it effectual not only for them, but for all insects that feed on the foliage of trees or plants. No other preparation, as I am aware, has yet been used that is so inexpensive and easily prepared and applied as this. It is a perfect protection to the melon and squash vines against the ravages of the striped bug, to rose bushes from the slug, and the currant and raspberry from the worm. This is as far as my experience extends, but I see no reason why the cankerworm and the caterpillar could not be destroyed by this preparation. Last season I applied the Paris green to my trees, and I was satisfied that it had its effect on the curculio, but the season was so cold and wet here, and insects generally were so scarce and the fruits rotted so badly, I could not fully decide. But this season the unusual warm weather brought them out early, and on noticing their marks on the fruit I made an application of the green to my trees and repeated it every week or ten days. The fruit that was stung dropped off, but it is the last I have seen of the curculio, although in other localities where it has not been used they have been constantly at work. My manner of using this poison is to mix 30 parts of flour or fine middlings to one of the Paris green (this is the same proportion that we use on our potato vines); take a two or three quart tin pail and perforate the bottom and fasten to a pole, and while the dew is on shake it over the tree, standing on the windward side and not inhale any of the dust. A slight dusting is sufficient, and it will be found strong enough for all practical purposes.

The value of Paris green for this insect was questioned by Dr. Riley in the American Entomologist and Botanist for October, 1870, and the paragraph which appeared there also appeared in his Third Missouri Report, published the same year. Riley states:

Even if the uniform application of such a poisonous drug on large trees were true, it would never succeed in killing one curculio in a hundred. Paris green kills the leaf-eating beetles by being taken internally with the larvæ, but the curculio, with its snout, prefers to gouge under the skin of the fruit, and only exceptionally devours the leaves. Yet, notwithstanding the palpable absurdity of the remedy, it is very generally passed from one journal to another without comment.

It would seem that the suggestion by Mr. Smith in 1870 was very generally copied in the horticultural and agricultural journals of the day. The writers, however, have not been able to find references to the subject during the interim from 1870 to about 1880. The recommendation had apparently not made much impression, for in an extended article on the plum curculio, dealing especially with remedies, Mr. B. Gott, in the Annual Report of the Entomological Society of Ontario (1879), makes no mention whatever of Paris green or other arsenicals.

[1] Moore's Rural New Yorker, vol. 22, p. 45, 1870.

By the early eighties, however, Paris green had come into some use. Thus Riley and Howard record the case of Mr. J. Luther Bowers, of Herndon, Va., who had informed these gentlemen that during the summer of 1880, while he was living in Clark County, Va., he had sprayed his trees with Paris green in the proportion of 1 tablespoonful of green to 5 gallons of water, making the application with a Whitman fountain pump. He sprayed soon after the petals fell and again in a week or ten days. The result was the most perfect crop of plums he had ever grown.

In his annual address as president of the Ontario Entomological Society, delivered October 15, 1884, Mr. William Saunders, concerning the Paris green treatment for the curculio, said:

From the evidence thus far obtained it would appear that the remedy which has been found so efficacious in subduing the codling moth of apple, namely, Paris green and water in the proportion of a tablespoonful of the poison to a pail of water, will also protect the plum crop from the ravages of the curculio.

Under the caption "Paris green and the curculio," Mr. William Creed, writing in Purdy's Fruit Recorder for November, 1885, states:

In the October number of the Fruit Recorder of the present year, you invite the experience of those who have experimented with Paris green upon the curculio. You will find a record of facts in this direction, from my pen, in your paper dated August, 1884, and until some tangible refutation can be produced by others to affect its value, it should not be looked upon with distrust. That Paris green will "do the buisness" for the little Turk, I think is irrefutable—certainly it is so from my own knowledge and trial for the three last seasons, and I will say positively that on very close investigation upon this year's crop, I have not had one plum, prune, or damson fall from the punctures of a curculio. But previous to the use of this remedy I looked upon plum culture with an instinctive dismay almost ungovernable, on account of its non-reliability. Of course, it is not for me to force an argument or intrude too much upon your columns concerning this curculio remedy, but will simply crave a little space to show the sample of some plum growers' logic when told of my experiments and results. The whole batch of arguments by these men do not, however, amount to a "row of pins." The following "walks and talks" happened in 1884. The first was with a nurseryman, who said, so far as 1884 was concerned, he considered the apparent success as stated was no criterion to go by, as it was a great plum year in this neighborhood. The second talk was with a gentleman who has about 5 acres of plums, prunes, and damsons. He would not listen to the subject a moment. "But," said I, "you now have coming into bearing a fine lot of nectarine trees and you may want a curculio remedy," and I at once suggested the intelligent use of Paris green by spraying, but to no avail. "Shaking," would do for him. The third gent was from Michigan and editor and proprietor of a paper and a lover of good fruits, but hater of the curculio, which was evidenced by saying that his remedy for the curculio was to cut the tree down, which he had done, and bought his plums from distant localities where the insect is less plentiful and the plum crop more to be depended upon.

You will see from the foregoing that there is but poor encouragement and little temptation to introduce a good thing, and had you not invited another year's experience, I should have let the matter drop. Let it be understood that I do not claim priority of suggestion of the use of Paris green for the extinction of the curculio, as there may have been thousands of others investigating the matter on the same basis and about which I am totally ignorant; but what I do know is that I gave you my

method after a second year's trial, and as in this case, so also with regard to pear blight, I first put forth my theory of the latter in the Fruit Recorder, as being among the papers with the largest circulation and as most likely to meet with the largest results and attention; and in November, 1877, when I classified pear blight as a zymotic disease and suggested an investigation upon this theory it was apparently at once taken up by Prof. Burrill and continued by other professors of microbotany, and to-day the bacterian theory of pear blight has become an established fact and the prevention or modification of the disease may be looked upon with a degree of certainty at no distant day. Now for some one to step forward and supplant the first stepping-stone to the proper study of pear blight as it appeared in the Recorder of 1877.

In the spring of 1885, Dr. Riley, in an address before the Mississippi Valley Horticultural Society, at New Orlenas, La., discussing the feeding habits of the beetles, urged experimentation with arsenicals in this direction, as promising fair results—not, however, in the very nature of the case as satisfactory as in the case of the codling moth.

During the summer of the same year Dr. S. A. Forbes began experiments in Illinois in the control of the codling moth and apple and plum curculio, reporting the results in the Prairie Farmer of December 19, 1885, and also in the Transactions of the Illinois State Horticultural Society for that year, which appeared from the press the following year. Paris green and London purple were tried on apple. Paris green was used at the rate of three-fourths ounce to 2½ gallons of water (equaling approximately 1 pound to 50 gallons), the metallic arsenic present being 15.4 per cent. Two trees were sprayed eight times during the season, the first applications being made on June 9 and 13, respectively. Two trees of the same variety of apple were left unsprayed for purposes of comparison.

In regard to the effect of the treatment of the curculio, Prof. Forbes says:

Of the 1,975 apples from these two poisoned trees which were examined for the curculio injury, 542, or 27.3 per cent, bore the brand of the insect's beak, while of the 1,172 obtained from the check trees, 602, or 57.3 per cent, had been so injured, the ratio of apples punctured by the curculio on the poisoned trees being half as many times on the trees that had not been sprayed. A careful inspection of our tables showed that this was a fact apparent throughout the season. Considering the picked apples only the results are somewhat more favorable, and if the fallen apples are also taken into count, the percentage of those damaged by the curculios on the check trees being 76.5 and upon those sprayed with Paris green 34.4 per cent.

During the summer of 1886 Prof. Forbes continued his experiments with arsenicals in the control of the codling moth, particularly comparing Paris green and white arsenic, noting also the effect of the treatments on the curculio.

These experiments by Prof. Forbes seem to be the first careful ones made to determine the value of arsenicals in curculio control. In an earlier part of his article Prof. Forbes notes that Paris green had been very generally recommended.

In the report of the secretary of the State Board of Agriculture for Michigan for 1887, Prof. A. J. Cook reports upon Paris green for the curculio as follows:

Paris green in the proportion of 1 tablespoonful to 6 gallons of water was very thoroughly sprayed upon 4 plum trees May 18. The petals had all fallen, but the dried calyces still clung to the fruit. On August 20 the trees were visited, when it was found that the two treated trees of the wild goose variety had dropped all their fruit, as had the untreated trees of the same kind. Another treated tree of a yellow variety was loaded with plums, of which only 15 per cent were stung and those not badly. The fourth treated tree was a purple variety and had not less than 75 per cent of its fruit badly stung.

During the season of 1887 experiments were begun with Paris green sprays by Prof. W. B. Alwood, at that time an agent of the Division of Entomology of this department, as detailed in the Report of the Entomologist for that year. These experiments were not begun until after the beetles had commenced work. No definite inferences in regard to the experiments may be drawn, since these were not finally concluded. Prof. Alwood thought, however, that the curculios ate enough to make it possible to poison some of them, but the benefit derived was in his opinion yet unsettled.

In Bulletin 3 of the Ohio Agricultural Experiment Station, issued in May, 1888, Prof. C. M. Weed, under the caption "Experiments with remedies for the plum curculio," announced proposed tests of three specified methods of control of this insect, and adds:

Spraying with London purple or Paris green as soon as the blossoms fall as recommended for the apple. I am reliably informed by many of the largest fruit-growing firms of western New York that in this way they succeeded in avoiding the curculio and raised large crops of plums. The method has been recommended at various times for several years, but as yet has certainly received little attention.

The same season Prof. Weed put into effect his line of treatment, the results of which were given in Bulletin 4 of the Ohio Station, which appeared in July. A young orchard of early Richmond cherries was employed, and in regard to his work he concluded as follows:

(1) That three-fourths of the cherries liable to injury by the plum curculio can be saved by two or three applications of London purple in a water spray (in the proportion of 1 ounce to 5 gallons of water) made soon after the blossoms fall. (2) That if an interval of a month occurs between the last application and the ripening of the fruit no danger to health need be apprehended from its use. As a precautionary measure, however, I would advise in all cases, and especially where there are few rains during this interval, that the fruit be thoroughly washed before it is used.

Prof. Weed continued his studies of spraying for the curculio in 1889, using also the early Richmond cherry. His statement of results covering two seasons' work on cherry is as follows:

This series of experiments carried on through two seasons upon two varieties of cherry trees and four varieties of plum trees, during which a total of 6,500 cherries have been individually examined, seems to me to confirm the conclusions provisionally announced one year ago, which may now be put in the following form: (1) That about

three-fourths of the cherries liable to injury by the curculio can be saved by two or three applications of London purple in a water spray in the proportion of 1 ounce to 10 gallons of water. (2) That a sufficiently large proportion of the plum crop can be saved by the same treatment to insure a good yield when a fair amount of the fruit is set. (3) That if an interval of a month or more occurs between the last application and the ripening of the fruit no danger to health need be apprehended from its use. (4) That spraying with the arsenicals is cheaper and more practical than any other known method in preventing the injuries from this insect.

During the season of 1890 spraying experiments on a commercial scale were carried out by Mr. Weed in an orchard of 900 five-year-old plum trees in the fruit belt along the lake shore in northern Ohio, and a comparison was made relative to the merits of spraying versus jarring. As a result of this test several plum orchards in northern Ohio were sprayed for the curculio during 1891 and the consensus of opinion of the growers was in favor of the practice. Tests were also made the same season by the horticulturist of the Ohio Station, Prof. W. J. Green, both on the station grounds and in Ontario County, Ohio. Paris green was used in combination with Bordeaux mixture. The results on sprayed trees showed that about 20 per cent were injured by the insect, whereas unsprayed trees had about 70 per cent of injured fruit.

Prof. Herbert Osborn, at that time an agent of the Division of Entomology of this department, also carried out spraying experiments in the use of arsenicals against the curculio during the summer of 1888. The poison used was London purple, at the rate of one-half pound to 100 gallons of water, with the addition of a small amount of soapsuds. The first treatment was given June 1, when the fruit was the size of small peas and before any indications of injury by the insect were to be found. The results of counts of all fruit from several varieties treated, sprayed and unsprayed, gave for the sprayed trees 32.48 per cent stung and 5.71 per cent containing larvæ. The unsprayed trees gave 41.86 per cent stung and 10.39 per cent of the fruit infested. It was concluded that the proportion of fruit stung in the orchard was so small as to give no benefit from spraying.

London purple was also tested during the season of 1888 on plums by Mr. G. C. Brackett, at Lawrence, Kans. Prof. Cook, in Bulletin 39 of the Michigan Agricultural Experiment Station, issued in 1888, says:

It will be remembered that I have used the London purple several years with quite indifferent success to keep out principally the curculio. The fact that some fruit growers reported excellent success with this remedy led me to conclude that possibly I had not been persistent and thorough enough in this warfare. The curculio commences to work anywhere on the plum, which has a smooth surface, while the codling moth lays its egg right in the cup or funnel-like calyx end of the apple. Thus the wind and rain would free the plum or cherry or general surface of the apple of the poison much more readily and quickly than they would the rough cavity end of the apple. Thus we can understand how, granting that the arsenites are alike effective

against the codling moth and curculio, more care would be required in resisting the attack of the latter. This season we arranged our experiments with this point directly in view. On June 4, the trees, both plum and cherry, were jarred and curculio were caught. The mark of the curculio was also found on both cherries and plums. The trees were sprayed June 6, June 12, and June 20. The material was the same as that used in spraying the apples, namely, 1 pound London purple to 100 gallons water. Careful examinations June 12 found no stung cherries and very few plums. June 26, 250 cherries were picked from the sprayed trees, and not one was injured. The crop of cherries was large and no cherries from the sprayed trees were wormy. July 16 and 18 the fallen plums were all gathered under the trees and cut open. On tree No. 1 there were 16 plums, of which 10 were wormy. Tree No. 2 (wild goose), 117 plums, 23 wormy. Tree No. 3 (Washington), 33 plums, 3 wormy. Close examination found no stung plums on the trees, and the crop upon picking was very free from injury. Cherry and apple trees near by not sprayed suffered seriously.

CONCLUSIONS.

From these experiments and those of former years I conclude that while one application will not save our plums and cherries and prevent apples from being stung, two or three applications may be of signal advantage.

In 1888 Prof. Forbes began a series of observations to determine some details of the food and feeding habits of the curculio and to test its susceptibility to arsenical poisons when distributed on the trees frequented. Observations were also made on a strength of poison which might be used on peach foliage without marked injury. As a result of his studies he concluded:

There can certainly be no further question of the liability of the curculio to poisoning by very moderate amounts of either London purple or Paris green while feeding on the leaves and fruit of peach and plum, but much additional experimentation is needed to test the possibility of preventing serious injury to these fruits by this means. The pupal hibernation and late appearance of a considerable percentage of the curculios make it possible that spraying must be several times repeated and perhaps carried further into the season than is consistent with safety; and the limit of tolerance of these poisons by the peach under ordinarily trying circumstances had not been clearly ascertained. Further, the observations reported above on the food plants of the curculio make it likely that in nature a smaller proportion of the food of these beetles comes from the peach or plum than has hitherto seemed possible, and that poisons there applied would kill less certainly. It seems worth while to make the attempt to attract the adult to flowering plants in the orchard other than the peach, with the hope of poisoning it there (especially late in the season) without using these dangerous insecticides on fruits afterwards to be eaten.

Prof. C. P. Gillette, in Bulletin 9 of the Iowa Agricultural Experiment Station, issued in May, 1890, records observations on the curculio and plum gouger, giving results of spraying plums with London purple for the control of both of these insects. His work led him to believe as follows regarding the efficiency of arsenicals:

The two applications of London purple and water, although not made at the times best suited to destroy the curculio, apparently gave a protection of 44 per cent against the ravages of this insect.

London purple and water in the proportion of 1 pound to 120 gallons is much too strong a mixture for plum trees. One-half of this strength is as strong a mixture as should be used.

In summing up the situation as to the use of arsenicals against the curculio, in 1887, Riley and Howard state:

On the whole, the remedy is one which is a desirable addition to our list, although it will never become so great a success as the application of the poisons for the codling moth, and for two reasons: (1) The egg is deposited and the beetle gnaws preferably upon the smooth cheek of the fruit where the poison does not readily adhere and from which it is more easily washed off; (2) the larva eating directly from the flap does not come in contact with the poison as does the larva of the codling moth.

The foregoing will give a fair idea of the rise of spraying with arsenicals for the curculio. By about 1890 the practice unquestionably had become rather general, although jarring was still employed by many growers. The injury to the foliage of stone fruits by such arsenicals as Paris green and London purple, frequently noted by orchardists and the early experimenters, no doubt greatly retarded the adoption of these poisons. The development, however, in 1892, by the Massachusetts Gipsy Moth Commission, of arsenate of lead, an insecticide much less caustic to the foliage than either Paris green or London purple, gave a considerable impetus to spraying for the curculio, especially on peaches and plums. Spraying, however, had been in effect two decades or more before its real merits on a commercial basis had been determined. The careful experiments of Forbes, Weed, Alwood, and perhaps others, had shown unmistakably that the injuries could be materially reduced by frequent spraying, and the testimony of many fruit growers was decidedly in favor of it. There were others, however, who doubted its efficiency, and continued the practice of jarring.

FEEDING EXPERIMENTS WITH POISONS.

The point has several times been raised in the case of arsenate of lead whether this did not act mainly as a repellent; and in an experiment by W. W. Chase a report bearing on this question is given.[1] A single small peach tree was covered with fine wire screen. The tree was literally soaked with lead arsenate, 3 pounds to 50 gallons of water, and after the poison had dried another application was given. The day following, May 11, 372 curculios which had been confined 48 hours without food were liberated in the cage. Subsequent close observation failed to discover a single beetle feeding on the tree, and in fact the beetles seemed to have the strongest aversion to it. At the end of 10 days all the beetles were dead, except a few which may have escaped. It would appear to the writers that in this case

[1] Bul. 32, Georgia State Board Entomology, p. 27.

the poison was applied much too freely, and as used would undoubtedly have acted as a repellent. In the case of Paris-green sprays in water there could be no repellent action attributed, and with arsenate of lead, as used in practice, it would seem established that its value lies more in killing of the insects than in possible repellent action.

In the course of these studies numerous feeding tests have been made with the curculio, especially with different brands of arsenate of lead and other miscellaneous arsenicals. Results of a feeding test made in 1906 are shown below (Table XC), where apple, pear, peach, plum, and cherry branches bearing foliage and fruit were used. Twigs of plants placed in bottles with water were used and all were sprayed at some time with arsenate of lead at the rate of 2 pounds to 50 gallons of water, using a hand pump and Vermorel nozzle. With each fruit the poison test was made in duplicate with a single check. After the spray had dried on the foliage the branch was placed under a large cylinder with cloth over top, and 20 beetles, collected that morning by jarring, were added.

TABLE XC.—*Tests of the killing effect of arsenate of lead on the plum curculio on specified fruits, Washington, D. C., 1906.*

Dates of examination.	Apple.			Pear.			Peach.			Plum.			Cherry.		
	Poisoned No. 1.	Poisoned No. 2.	Not poisoned.	Poisoned No. 1.	Poisoned No. 2.	Not poisoned.	Poisoned No. 1.	Poisoned No. 2.	Not poisoned.	Poisoned No. 1.	Poisoned No. 2.	Not poisoned.	Poisoned No. 1.	Poisoned No. 2.	Not poisoned.
June 25	6	10	....	4	2	....	1	4	....	4	6	....	2	1	1
26	4	2	....	3	6	....	2	4	....	5	3	....	4	4	....
27	4	2	....	6	6	1	10	5	....	3	3	....	7	7	....
28	2	2	1	6	2	2	....	4	1	5	1	....	4	5	1
Total	16	16	1	19	16	3	13	17	1	17	13	....	17	17	2
Beetles alive at close of observations	4	4	19	1	4	17	7	3	19	3	7	20	3	3	18

The results uniformly show a prompt killing effect on the beetles by the arsenate of lead on the varieties of fruits used. It is also evident that the insects feed freely during midsummer.

During 1910, in Georgia, numerous feeding tests were made using several of the more important brands of arsenate of lead, as well as other miscellaneous arsenicals. In Table XCI are given results of feeding tests on peach twigs taken from trees in orchards immediately after spraying, April 13 and 14, and placed under cylinders. April 16, 50 beetles were added to each cylinder and records made daily of the number of beetles dying. The poisons were used of the strength indicated in the foliage test experiments (p. 205). The killing effect of all of the poisons was fairly prompt, the various brands of arsenate of lead working fairly uniformly. Red arsenic sulphid and arsenic tersulphid were quicker in action than the lead arsenates, although, as elsewhere noted, these poisons were notably injurious to the foliage of

peach. Ferrous arsenate was much slower in action, but effective, as shown by comparison of the condition of beetles fed on poisoned foliage with the condition of the beetles on the check.

TABLE XCI.—*Tests of killing effect of lead arsenates and other arsenicals on the plum curculio on peach, Georgia, 1910.*

Dates of death of beetle.	Beetles dying from each of the arsenicals.													
	Check not sprayed.	Arsenate of lead.								Powdered arsenate of lead.	Ferrous arsenate.	Red arsenic sulphid.	Arsenic tersulphid.	Arsenic tersulphid.[1]
		No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.					
Apr. 17													3	
18		4	1		4	8	4	4	4	5		9	17	
19		2	3	4	1	5	7	8	16	1	1	9	16	
20	1	8	5		5	3	2	3	7	4		3	1	
21	1	9	12	7	6	4	6	11	4	5	2	8	4	
22		7	6	5	10	9	5	6	4	5		2	5	1
23		8	13	8	7	5	10	10	7	5	3	6	2	6
24		2	2	8	8	7	3	1	5	7	2	3	1	8
25		3	1	5	5	4	6	3	1	6	3	1		11
26		3	2	3	1	2	1	2	2	5	7	4		3
27		2	2							4		1		8
28		1	1	3		1	3			1	5			7
29	1		1	3	2	2	1	2		1	7	4		3
30				3							4			2
May 1				1							5			1
3											2			
4	1										3			
5											1			
6											1			
7	1													
8											1			
9											1			
11	2													
13	6													
14	1													
15	2										1			
16	4													
17	2													
18	1													
23	1													
24	1													
25	1													
26	2													
June 3	1													
6	1													
8	1													
13	15													
Total.	46	49	49	50	49	50	48	50	50	49	49	50	49	50

[1] Duplicate test started Apr. 20.

In Table XCII are shown results of feeding tests with several miscellaneous arsenicals, as specified, used in the self-boiled lime-sulphur wash and simply in lime water. As before, twigs were cut from peach trees in sprayed plats in orchards and placed under glass cylinders. Spraying was done April 28 and 30, and 50 beetles were added to each jar April 30. The beetles in all of these tests were fresh, having been jarred from peach trees a day or so previous. An accelerated killing effect seems to have followed the use of the combined self-boiled and arsenical sprays, as compared with the arsenical used alone. The comparatively slow action of arsenate of iron is again noted, though when used in the lime-sulphur wash it compares favorably with arsenate of lead.

TABLE XCII.—*Tests of killing effect of various arsenicals on the plum curculio on peach, Georgia, 1910.*

Dates of death of beetle.	Beetles dying from each of the arsenicals.											
		Arsenicals used in self-boiled lime sulphur.							Arsenicals used without lime sulphur.			
	Check unsprayed.	Arsenate of lead.	Ferrous arsenate (powder).	Arsenate of iron (paste).	Arsenic tersulphid (powder).	Yellow arsenic sulphid (paste).	Red arsenic sulphid (powder).	Sulpho-arsenate of soda.	Ferrous arsenate (powder).	Arsenate of iron (paste).	Yellow arsenic sulphid (paste).	Sulpho-arsenate of soda.
May 2	......	3	4	3	11	2	11	3	1	7	3	1
3	......	5	4	3	8	2	7	3	......	1	16	6
4	1	6	3	1	7	5	15	8	2	1	3	3
5	......	7	4	3	5	12	8	7	5	1	2	3
6	......	11	5	10	2	9	1	20	2	4	1	5
7	1	9	9	10	8	8	3	6	8	9	8	4
8	......	3	3	2	5	1	1	......	1	4	9	4
9	......	2	1	7	1	3	1	1	4	2	5	10
10	......	4	2	1	......	1	1	1	2	4	1	4
11	2	......	3	3	......	3	......	......	5	1	2	3
12	......	......	2	3	1	1	......	......	4	5	......	3
13	6	......	6	1	1	......	......	......	......	......	......	1
14	1	......	2	1	......	......	......	......	7	2	......	......
15	2	......	2	......	......	......	......	......	4	1	......	1
16	4	......	......	......	......	......	......	......	2	1	......	......
18	3	......	......	......	......	......	......	......	......	......	......	1
19	......	......	......	......	......	......	......	......	......	......	......	......
20	......	......	......	......	......	......	......	......	1	2	......	......
23	1	......	......	......	......	......	......	......	......	......	......	......
24	1	......	......	......	......	......	......	......	......	......	......	......
25	1	......	......	......	......	......	......	......	......	......	......	......
26	2	......	......	......	......	......	......	......	......	......	......	......
27	......	......	......	......	......	......	......	......	......	1	......	......
29	......	......	......	......	......	......	......	......	......	1	......	......
June 3	1	......	......	......	......	......	......	......	......	......	......	......
6	1	......	......	......	......	......	......	......	......	......	......	......
8	1	......	......	......	......	......	......	......	......	......	......	......
13	18	......	......	......	......	......	......	......	......	......	......	......
Total	46	50	50	48	49	47	48	49	48	47	50	49

A feeding test was made with beetles in lots of 50, using twigs bearing fruit and foliage from sprayed trees in the orchard, except in case of lot 6, where foliage had been removed. Trees were sprayed, April 4 and 5, with arsenate of lead at the rate of 2 pounds to 50 gallons of water, and feeding tests started April 5, except with lots 7 and 8, which were started April 7. It will be noted that all the beetles on the sprayed branches were killed within about a week, except lot 6, where fruit only was present and the period was lengthened. (See Table XCIII.)

TABLE XCIII.—*Tests of killing effect on the plum curculio of arsenate of lead sprayed on peach foliage and fruit, Georgia, 1910.*

Date of death of beetle.	Beetles dying in each lot.							
	Lot 1: Unsprayed twigs with fruit and foliage.	Lot 2: Sprayed twigs with fruit and foliage.	Lot 3: Unsprayed twigs with foliage only.	Lot 4: Sprayed twigs with foliage only.	Lot 5: Unsprayed twigs with fruit only.	Lot 6: Sprayed twigs with fruit only.	Lot 7: Unsprayed twigs with fruit and foliage.	Lot 8: Sprayed twigs with fruit and foliage.
Apr. 6	1	3				2		
7	1	3				1		
8		6		4		3		2
9		8		22		3	2	12
10	4	15		19		14		16
11		4	2	4		1		6
12		7	1	1	1	1		9
13	1	1	2		1	7		5
14						2		
15						2		
16			2			1		
17			3					
Condition on Apr. 17.	Lot 1.	Lot 2.	Lot 3.	Lot 4.	Lot 5.	Lot 6.	Lot 7.	Lot 8.
Total died	7	47	10	50	2	37	2	50
Alive	42		36		46	9	46	
Escaped	1	3	4		2	4	7	

Some feeding tests made by Mr. Johnson to determine the possibility of preventing the fall-feeding punctures of the curculio on apple are interesting:

August 17, a branch of Baldwin apple tree bearing fruit, after spraying with arsenate of lead at the rate of 3 pounds to 50 gallons of water, was inclosed in a cage with 50 beetles. Twenty beetles had died by August 28. An examination of the apples showed 3 without punctures and 8 with punctures, as follows: Fruit No. 1, 5 punctures; No. 2, 7; No. 3, 14; No. 4, 15; No. 5, 16; No. 6, 28; No. 7, 41; No. 8, 49; a total of 175 punctures on the 8 fruits.

The condition of a check branch bearing 8 apples on this date was: Fruit No. 1, 66 punctures; No. 2, 14; No. 3, 45; No. 4, 18; No. 5, 26; No. 6, 58; No. 7, 23; No. 8, 63; a total of 343 punctures. None of the beetles was dead in this cage and the punctures were much larger.

SPRAYING FOR THE CURCULIO ON APPLE.

EARLY EXPERIMENTS.

The first experiments of which we are aware, made to determine the value of arsenicals in the control of the curculio on apple, are those reported by Forbes in 1885, and already referred to (p. 181). In this work 8 trees were used, 4 of them being sprayed and 4 reserved as checks. Two of the trees were treated with Paris green, 1 with London purple, and 1 with lime. Two applications were

made 8 times, beginning June 9 and continuing until September 3. The two trees sprayed with Paris green at the rate of 1 pound to 50 gallons of water showed a benefit in lessening curculio injury as compared with the unsprayed trees of about 50 per cent—more exactly, 72.70 per cent of the fruit was uninjured as against 42.70 per cent uninjured on the unsprayed trees. The trees that had been sprayed with London purple gave 61 per cent sound fruit as against 62 per cent fruit from the unsprayed trees. In conclusion Prof. Forbes states:

> Furthermore, if we must judge from results thus far reached, these various applications are all of too slight effect upon the apple for plum curculios to make them worth use against these insects, Paris green diminishing curculio blemishes less than one-half, London purple about one-fifth, and lime not far from one-fourth.

No further experiments seem to have been made until 1900, at which time Prof. Stedman began an investigation of the curculio on apple, which was continued during 1901 and 1902, the results of which are given in the bulletin of the Missouri Agricultural Experiment Station No. 64, published in 1904. Experiments in spraying apples were made in three different orchards. It was desired to test the practicability of killing the beetles while they were feeding on the leaves before the appearance of the bloom. One-half of each orchard was sprayed twice from the time the leaves opened until the blossoms opened, leaving the other half as check. These experiments were repeated the following year, and in addition four applications were given after the falling of the blossoms at intervals of 10 days. By this means about 60 per cent of the fruit was protected in spite of reinfestation of the sprayed trees from the unsprayed part of the orchard. The desirability of spraying the entire orchard to prevent overflow was pointed out, as under these conditions the benefits would be very marked, and the great bulk of the "stings" would be prevented.

In the report of the Illinois State Horticultural Society for 1902, page 158, Prof. E. S. Titus discusses the plum curculio under the caption "Insects other than the codling moth injurious to the fruit of apple," and gives results of observations made at the instance of Dr. Forbes. In regard to the use of arsenicals he says:

> The experiments tried in the Illinois entomologist's office several years ago showed very clearly that the curculio may be killed by spraying trees to which it resorts in early spring with Paris green or other arsenical poisons, as it feeds at that time largely on young leaves. Consequently, other things being equal, that orchard will be least infested and its fruit least injured whose trees are sprayed early in the spring, as for the codling moth or canker worm. On the whole, however, much the most promising and important measure is the prompt destruction of fallen apples to prevent the escape of the curculio larvæ into the earth, after which it is almost impossible for these larvæ to go through their usual transformation.

The first attempt, however, to determine the possible value of the use of arsenical poisons in the control of the curculio on apple on a commercial scale was begun by Prof. C. S. Crandall, of the Illinois Experiment Station, in 1903. His report of operations for that year was read before the Illinois State Horticultural Society (vol. 37, pp. 176–189). Two blocks of sixty 18-year-old trees each in two different but adjacent orchards were selected. In the Williams orchard the soil was covered for the most part with a bluegrass sod with a heavy surface mulch of dead leaves and grass. In the Blair orchard there was no sod but a scattered growth of plants, including grasses, and the surface mulch of leaves and trash was lighter. From 7 to 16 applications of an arsenical spray were given to the respective plats, including Paris green, arsenate of lead, white arsenic, and arsenite of lime, the first three treatments in Bordeaux mixture and the subsequent ones in water. During the course of the work 29,943 apples were examined. In commenting on the results, Prof. Crandall states that the spraying did not control the curculio. Apparently the frequent spraying had some influence because the percentage of uninjured fruit from the plats sprayed 16 times was a little higher than from any other plats. Three reasons were assigned for the unfavorable results, namely:

1. Weather conditions of early spring and their bearing on the crop.
2. Location of the plats directly in the midst of large orchards contiguous to native woodlands.
3. Unusual abundance of the insects.

On the Williams orchard the percentage of sound fruit varied from 1.26 to 5.29, with an average for all plats of 2.76. Results were somewhat better in the Blair orchard, the percentage of sound fruit ranging from 2.55 to 16.07, with an average for the several plats of 7.13.

Prof. Crandall continued his work during 1904, as reported for the Illinois Horticultural Society (vol. 38, p. 75), and selected a somewhat isolated 5-acre orchard, thus eliminating invasion by the insect from outside sources. This entire orchard was treated, except the 13 check trees. The ground was not in sod and the orchard had never been sprayed. The spring weather was reasonably favorable and the trees bore a fair crop of fruit, and the curculios were much less abundant than in 1903. The schedule of applications was the same as employed in 1903. A total of 72,922 apples was examined from all of the plats, of which 23,956 were windfalls. The treatments and results are shown in Table XCIV.

TABLE XCIV.—*Results of spraying apples for plum and apple curculios in Illinois, 1904.*

Plat No.	Treatment.	Trees.	Total number of fruits.	Total number of fruits punctured.	Percentage of sound fruit.
I	3 applications Bordeaux mixture and Paris green (check)	13	10,185	7,617	25.21
II	10 applications Paris green, ½ pound to 50 gallons water	14	14,352	7,931	44.74
III	16 applications Paris green, ½ pound to 50 gallons water	13	10,861	4,118	62.08
IV	8 applications Paris green, ½ pound to 50 gallons water	15	12,735	7,066	44.52
V	7 applications arsenite of lime	13	11,592	6,321	45.47
VI	7 applications arsenate of lead	12	13,197	7,310	44.61

All of the plats, including the check (Plat I), were sprayed three times with Bordeaux mixture and Paris green, one-fourth pound to 50 gallons of the Bordeaux, to protect from apple scab and the codling moth, and three sprayings on the checks reduced curculio injury, as shown by other trees in the orchard entirely unsprayed, 15.21 per cent. The marked influence of seasonal and local conditions on curculio injury is very forcibly shown in the Illinois results. The treatments in 1903 showed no benefit as regards control of the insect, whereas in another orchard in 1904 the saving in fruit from trees liable to injury ranged from 27.65 per cent to 54.53 per cent. Prof. Crandall states:

To sum up the matter of spraying for the curculio from the standpoint of results obtained during the two seasons of 1903 and 1904, it seems possible that under favorable conditions and with a reasonable number of applications to control curculios to the extent of from 20 to 40 per cent of the possible injury. There is benefit to be derived from spraying but not that degree of benefit which would warrant commendation of spraying as the one great panacea of injury done by the curculio.

In the proceedings of the Illinois Horticultural Society for the year 1904 (p. 91) Dr. Forbes, in continuation of his study of the curculio in Illinois apple orchards begun in 1901, reports results of experiments with arsenical sprays carried out in Southern Illinois and independent of the researches of Prof. Crandall, just alluded to. Four plats were established, including the check, and 4, 6, and 8 applications of arsenate of lead were given, beginning May 6 to 10, when the trees were in first full bloom, and repeated at intervals of about 10 days, ending July 28. Prof. Forbes presents the figures of yield of sound and injured fruit, though the experiment loses some of its value for the reason that the trees were of different varieties and the plats not all under the same conditions, being located in three different orchards, although all were on the same farm. Prof. Forbes summarizes as follows:

Finally, to sum up in a word the most important practical results of the orchard experiment with arsenate of lead, we may say that four sprayings, apple trees of old varieties exposed to a very heavy attack by the plum curculio, the first spraying applied in early May just as the trees were coming into bloom and the others at intervals of 10 days thereafter, the whole operations costing 17 cents per tree, may be expected

to increase the yield of the orchard about one-half, to increase the average size of the fruit about one-fifth, and so to improve the quality of the apples that they should be worth from 2½ to 3 times as much as if the orchard had not been sprayed.

These experiments were also reported in a paper before the American Association of Economic Entomologists, December, 1904, and in Bulletin 108 of the Illinois Agricultural Experiment Station, in which latter publication data are given showing the considerable movement of the beetles from the check to adjacent sprayed plats, a factor in results which has not heretofore been given sufficient consideration.

EXPERIMENTS BY THE BUREAU OF ENTOMOLOGY.

During the past few years the Bureau of Entomology has carried out spraying experiments against the curculio in different parts of the country and under varying orchard conditions. The importance of the subject warrants the presentation of results in some detail.

EXPERIMENTS AT ANDERSON, MO.

The work at Anderson, Mo., was under the immediate direction of Mr. F. W. Faurot and was accomplished in cooperation with the Missouri State Fruit Experiment Station. The orchard consisted of a fair selection of varieties of 11-year-old trees in good condition. In addition to the purely demonstration spraying for insects and diseases, a test of dusting against spraying was planned on the Lansingburg variety of apple. The block of Lansingburgs consisted of 6 rows across one end of an 80-acre orchard and was divided into 6 plats, including the check. In Table XCV Plat II is omitted, as it duplicates Plat III, except that a less number of treatments was given, namely 9. This variety bore a good one-fourth crop. The dust was applied with a power duster driven by a gasoline engine. The liquid spray was also applied with a gasoline-power outfit except for the application immediately following the falling of the petals. The soft condition of the ground at this time from rains necessitated the use of a barrel outfit, though the pressure as shown by the gauge was maintained at 125 pounds. The plats contained trees as follows: I, 32; III, 35; IV, 70; V, 67; VI, 12. The check trees were in two rows across the center of the block. The number of trees from which all fruit was gathered and counted throughout the season for each plat is shown in the table. At the time of the first application, March 21 to 24, cluster buds were open; and at the time of the second application, April 14 to 16, the petals had been down for 4 or 5 days.

TABLE XCV.—*Results of spraying Lansingburg apples for the plum curculio, Anderson, Mo., 1908.*

Plat No.	Treatment.	Dates of applications. Mar.	Apr.	Apr.	May.	June.	June.	July.	July.	July.	Aug.	Aug.	Aug.	Sept.	Tree No.	Total number of apples.	Total number of apples punctured.	Total number of punctures.	Percentage of sound apples.	Average percentage of sound apples.
I.....	Homemade dust (lime 100 pounds, bluestone 5 pounds, Paris green 2½ pounds)................	24	14	25	8	16	25	6	15	29	8	19	27	5	1	255	248	2,185	2.74	......
															2	189	178	1,045	5.82	......
															3	784	763	5,657	2.67	......
															4	240	215	1,297	1.04	......
															5	380	373	1,320	1.84	......
																1,848	1,777	11,504	......	3.84
III...	Commercial dust..........	24	14	25	8	16	25	6	15	29	8	19	27	5	1	926	757	3,178	18.25	......
															2	1,037	785	2,157	24.30	......
															3	668	500	1,135	25.15	......
															4	574	369	1,438	35.71	......
															5	488	464	2,877	4.91	......
																3,693	2,875	10,785	......	22.15
IV...	Bordeaux mixture (4-4-50) plus ½ pound Paris green	21	16	..	5	..	23	..	14	..	3	26	..	..	1	640	368	789	42.50	......
															2	835	420	762	49.70	......
															3	772	396	698	48.70	......
															4	309	154	337	50.16	......
															5	427	241	419	43.55	......
															6	594	288	529	51.51	......
																3,577	1,867	3,534	......	47.81
V....	Bordeaux mixture (4-4-50) plus 2 pounds arsenate of lead.....................	21	15	..	5	..	23	..	14	..	3	23	..	..	1	1,397	600	1,072	57.05	......
															2	1,043	502	952	51.86	......
															3	757	411	942	45.71	......
															4	815	362	657	55.58	......
															5	1,047	437	723	58.26	......
															6	426	105	165	75.35	......
															7	1,205	429	718	64.40	......
																6,690	2,846	5,229	......	57.45
VI...	Untreated................	..	..	..	..	..	..	..	..	..	..	..	..	..	1	169	166	1,985	1.77	......
															2	308	297	2,104	3.57	......
															3	235	219	1,873	6.80	......
															4	298	286	2,063	4.02	......
															5	400	389	2,448	2.75	......
															6	368	364	2,275	1.08	......
															7	585	544	3,453	7.00	......
															8	516	481	2,741	6.78	......
															9	626	566	2,565	9.58	......
																3,505	3,312	21,507	......	5.51

As will be noted, results, so far as preventing puncturing of fruit by curculio, were decidedly poor. Plat I, receiving 13 applications of a homemade dust, was even more severely injured than the block of unsprayed trees, a condition doubtless due to its location. Best results were obtained on Plat V, which had the usual demonstration treatment, giving 57.45 per cent of sound fruit as against 5.51 per cent of sound fruit on the unsprayed trees.

The effect of the treatments on the curculio may be judged, perhaps, by the number of punctures per fruit. Thus, Plat I had an average of 6.22 punctures per fruit; III, 2.92; IV, 0.98; V, 0.78; and VI, 6.13.

EXPERIMENTS IN WESTERN NEW YORK AND NORTHWESTERN PENNSYLVANIA.

Results of demonstration spraying for apple insects and diseases in western New York (Westfield) and northwestern Pennsylvania (North East) as bearing on the control of the curculio are given in Table XCVI. In the Westfield work the average percentage of apples uninjured by the curculio from the 5 sprayed Baldwin trees used for counts was 91.07, as against 76.21 on the 5 unsprayed count trees, the average number of punctures per fruit for the former being 0.08 and for the latter 0.237.

In the case of Duchess trees at North East, Pa., notably better results are shown, which may in part be due to the earlier picking of the fruit of this variety, as avoiding late feeding punctures by the beetles. The 3 count trees of the sprayed block showed 79.04 per cent sound fruit, as against 25.44 from the 3 unsprayed count trees, a difference, in favor of two applications of poison, of 53.60 per cent of the crop. (See Pl. XV).

TABLE XCVI.—*Results of spraying apples for the plum curculio.*

WESTFIELD, N. Y., 1908.

Plat No.	Treatment.	Variety.	Tree No.	Total number of apples	Total number of apples punctured.	Percentage of sound apples.	Average percentage of sound apples.
I	Four applications Bordeaux mixture (4-4-50) plus 2 pounds arsenate of lead: May 6, May 27, June 8, June 27.	Baldwin	1	1,658	74	95.53	
			2	2,356	244	89.64	
			3	3,380	240	92.90	
			4	1,204	156	87.00	
			5	2,829	207	92.60	
				11,427	921		91.07
II	Unsprayed	do	1	748	191	74.40	
			2	1,518	309	79.60	
			3	862	181	79.00	
			4	1,100	212	80.80	
			5	838	312	62.77	
				5,066	1,205		76.21

NORTH EAST, PA., 1906.

Plat No.	Treatment.	Variety.	Tree No.	Total number of apples	Total number of apples punctured.	Percentage of sound apples.	Average percentage of sound apples.
I	Two applications Bordeaux mixture (4-4-50) plus 2 pounds arsenate of lead: May 24, June 7.	Duchess Oldenberg.	1	802	156	80.54	
			2	541	154	71.55	
			3	370	49	86.75	
				1,713	359		79.04
II	Unsprayed	do	1	647	473	26.89	
			2	268	223	16.79	
			3	146	95	34.93	
				1,061	791		25.44

EXPERIMENTS AT SILOAM SPRINGS, ARK.

In the one-spray versus demonstration treatments for the codling moth and apple diseases at Siloam Springs in 1909 special attention was given to determining the effect of these treatments on the curculio. The results from only Plats I, IV, and V are given as constituting the principal features of the work. The orchard was an isolated one and contained 344 trees and was divided into five plats. There was a miscellaneous assortment of varieties, but principally Ben Davis, on which variety all counts were made. The treatments which the respective plats received are shown in Table XCVII.

Plat I shows an increase in uninjured fruit over the unsprayed plat (Plat V) of 77.20 per cent, and there is a difference in favor of Plat IV of 3.74 per cent of sound fruit. It will be noted that one drenching spray in this instance gave somewhat better results than five applications, though this condition is probably to be accounted for by reason of the proximity of Plat IV to the check plat.

TABLE XCVII.—*Results of spraying apples for the plum curculio, Siloam Springs, Ark., 1909.*

Plat No.	Treatment.	Variety.	Tree No.	Total number of apples.	Total number of apples punctured.	Total number of punctures.	Percentage of sound apples.	Average percentage of sound apples.
I	One spraying only with arsenical; drenched with arsenate of lead, 1 pound to 50 gallons water, Apr. 24–25; Bordeaux mixture only (4–4–50) May 25–26, July 2.	Ben Davis	1	5,689	1,179	1,979	79.27	....
			2	4,813	915	1,713	80.98	....
			3	3,796	687	2,613	81.90	....
			4	2,750	387	683	85.92	....
			5	3,446	208	268	93.96	....
			6	3,768	532	1,012	85.88	....
			7	3,307	370	638	88.81	....
			8	5,443	706	1,200	87.02	....
			9	3,644	364	642	90.01	....
			10	2,652	216	319	91.85	....
			11	3,895	335	642	91.39	....
				43,203	5,899	11,709	....	86.34
IV	Five applications Bordeaux mixture (3–3–50) plus 2 pounds arsenate of lead: Apr. 24–25, May 25–26, July 2, July 22, Aug. 10.	do	1	3,536	746	1,293	78.90	....
			2	1,890	301	562	84.07	....
			3	5,076	437	773	91.39	....
			4	1,665	74	98	95.55	....
			5	3,145	266	430	91.54	....
			6	1,665	200	432	87.98	....
			7	2,496	498	1,025	80.04	....
			8	3,172	467	877	85.27	....
			9	4,791	1,656	3,129	65.43	....
			10	1,957	140	254	92.84	....
			11	3,058	769	1,429	74.85	....
				32,451	5,554	10,302	....	82.88
V	Unsprayed	do	1	2,560	2,130	6,623	16.79	....
			2	1,701	1,595	6,230	6.23	....
			3	995	948	4,331	4.72	....
			4	1,538	1,522	10,068	1.04	....
			5	1,206	999	3,372	17.16	....
			6	2,501	2,299	9,527	8.07	....
			7	2,821	2,724	14,727	3.43	....
			8	1,156	1,070	4,714	7.43	....
			9	2,323	1,936	6,143	16.65	....
			10	2,258	2,117	8,707	6.24	....
			11	1,719	1,605	6,921	6.63	....
			12	1,608	1,517	5,984	5.65	....
			13	2,060	1,750	6,739	15.04	....
				24,446	22,212	94,086	....	9.14

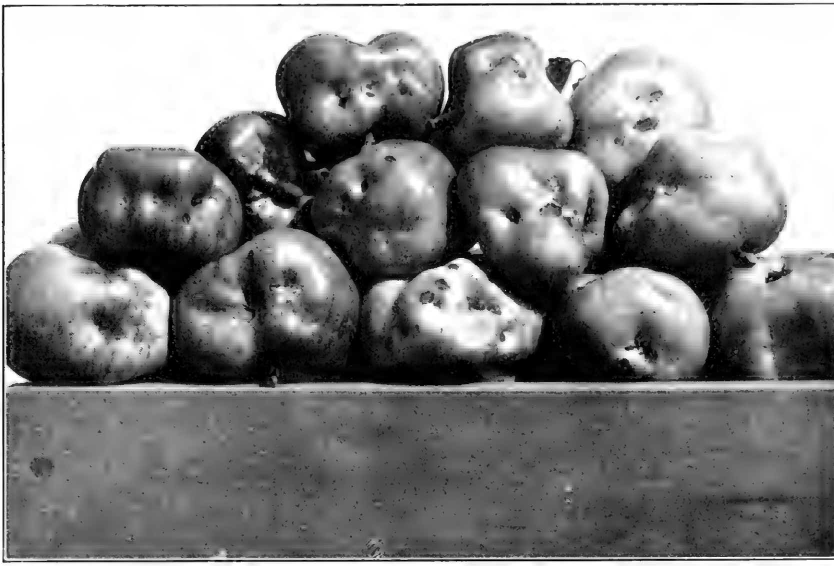


FIG. 1.—DUCHESS APPLES FROM TREES IN UNSPRAYED PLAT. (ORIGINAL.)

FIG. 2.—DUCHESS APPLES FROM TREES IN PLAT SPRAYED AGAINST THE PLUM CURCULIO WITH ARSENATE OF LEAD. (ORIGINAL.)

BENEFITS OF SPRAYING FOR THE PLUM CURCULIO.

EXPERIMENTS IN VIRGINIA.

Experiments in Virginia during 1909 were carried out in two localities, namely, at Crozet, in the orchard of Mr. W. S. Ballard, and at Mount Jackson, in the orchard of the Strathmore Orchard Co.

Orchard of Mr. W. S. Ballard.—This orchard is located in the eastern foothills of the Blue Ridge and is composed mostly of the Yellow Newtown variety, which sort was used exclusively in the experiments. The surrounding trees not used in the experiment were sprayed by the owner. This work formed part of the "one-spray" experiment, and especial attention was given to determining the effect of the treatments in lessening curculio injury. Four applications gave a percentage of 86.89 sound fruit as against 54.02 on the untreated trees, a difference of 32.87 per cent. One single drenching application protected from the curculio to an extent of 73.93 per cent, an improvement over the check of 19.91 per cent. (See Table XCVIII.)

TABLE XCVIII.—*Results of spraying apples for the plum curculio, Crozet, Va., 1909.*

Plat No.	Treatment.	Variety.	Tree No.	Total number of apples.	Total number of apples punctured.	Total number of punctures.	Percentage of sound apples.	Average percentage of sound apples.
I	Four applications Bordeaux mixture (2-2-50) plus 2 pounds arsenate of lead: Apr. 27, May 24, June 26, and July 26 and 27.	Newtown Pippin.	1	802	115	157	85.66	....
			2	1,459	187	275	87.18	....
			3	719	103	163	85.67	....
			4	2,415	345	524	85.71	....
			5	2,032	463	668	77.21	....
			6	1,308	114	162	91.28	....
			7	3,014	267	395	91.14	....
			8	2,328	252	328	89.17	....
				14,077	1,846	2,672	....	86.89
II	One spraying only, drenched with Bordeaux mixture (2-2-50) plus 2 pounds arsenate of lead, Apr. 27.	do	1	2,578	961	1,510	62.72	....
			2	2,533	730	1,290	71.17	....
			3	5,105	1,347	2,143	73.61	....
			4	1,318	238	360	81.94	....
			5	3,245	719	1,095	77.84	....
			6	1,979	405	647	79.53	....
			7	2,041	521	775	74.47	....
			8	2,039	511	823	74.93	....
				20,838	5,432	8,643	....	73.93
III	Untreated	do	1	3,423	1,255	2,746	63.33	....
			2	3,682	1,571	2,571	57.33	....
			3	816	437	705	46.45	....
			4	1,016	531	962	47.73	....
			5	3,111	1,415	2,490	54.52	....
			6	2,988	1,193	1,939	60.00	....
			7	1,980	1,098	1,865	44.54	....
			8	2,091	1,285	2,300	38.54	....
				19,107	8,785	15,578	....	54.02

Orchard of the Strathmore Orchard Co.—In the Strathmore orchard, at Mount Jackson, the curculio was notably more abundant, and the results were less favorable. The orchard had been in sod for some years and conditions were thus favorable for the insect. All trees not included in the experiment were sprayed by the owners.

The results indicate the impracticability of satisfactorily reducing curculio injury by spraying alone, when conditions are extremely favorable for the insect. Three applications protected the fruit to an extent of 40.82 per cent as against 27.23 per cent on the unsprayed trees, a gain of 13.59 per cent of the crop. Curiously, the single application, given to Plat II, resulted in a higher percentage of sound fruit than the three treatments given to Plat I, namely, 57.90, an increase over the check plat of 30.67 per cent.

TABLE XCIX.—*Results of spraying apples for the plum curculio, Mount Jackson, Va., 1909.*

Plat No.	Treatment.	Variety.	Tree No.	Total number of apples.	Total number of apples punctured.	Total number of punctures.	Percentage of sound apples.	Average percentage of sound apples.
I	Three applications Bordeaux mixture (1-1-50) plus 2 pounds arsenate of lead, May 6-7, 28-29, July 8-9.	Ben Davis	1	1,866	1,367	2,961	26.74	....
			2	1,308	755	2,391	42.28	....
			3	3,466	1,631	3,067	52.94	....
			4	708	441	932	37.71	....
			5	1,667	1,257	3,013	24.59	....
			6	3,786	2,197	4,040	41.97	....
			7	1,063	612	1,486	42.42	....
			8	2,429	1,382	2,869	43.10	....
				16,293	9,642	20,759	....	40.82
II	One spraying only, with arsenical. Drenched with arsenate of lead, 2 pounds to 50 gallons of water, May 6-7. Bordeaux mixture only (2-2-50), applied May 28-29 and July 8-9.	do	1	3,827	1,507	2,782	60.62	....
			2	3,657	1,788	1,800	51.10	....
			3	675	303	633	55.11	....
			4	989	494	1,032	50.05	....
			5	1,679	754	1,449	55.09	....
			6	3,480	1,212	2,159	65.17	....
			7	969	447	987	53.86	....
			8	4,299	1,735	3,153	59.64	....
				19,575	8,240	13,995	....	57.90
III	Unsprayed	do	1	3,926	3,186	7,336	18.84	....
			2	3,109	2,226	4,497	28.40	....
			3	1,840	1,079	2,212	41.36	....
			4	1,508	1,226	2,888	18.69	....
			5	3,189	2,399	5,030	24.77	....
			6	4,153	2,823	6,122	32.04	....
			7	5,121	3,611	8,779	29.48	....
			8	2,795	2,107	4,904	24.61	....
				25,641	18,657	41,768	....	27.23

EXPERIMENTS AT ST. JOSEPH, MO.

The work at St. Joseph also formed part of a demonstration schedule of spraying in comparison with the one-spray method. The orchard used had been in sod for some years, and no spraying had been done. Conditions were especially favorable for the insects, and, as shown by the tabulated results below, the injury under these conditions was very severe. The crop, moreover, was light by reason

of late spring frosts, which served to concentrate the injury. Unquestionably a part of the loss shown was due to the apple curculio, which was abundant in that locality. At the time of the first application, May 16, the petals had just fallen from the trees. The St. Joseph results present some points similar to those obtained the same year at Mount Jackson, Va.,—namely, that when the curculio is excessively abundant, satisfactory results may not be obtained by spraying. Plat I, which received 4 applications, shows only 50.10 per cent of sound fruit as against 4.05 from the unsprayed trees, representing a gain of 46.05 per cent. The single drenching application, given to Plat II, resulted in 36.80 per cent of fruit free from curculio, a gain over the unsprayed block of 32.75 per cent of the crop.

TABLE C.—*Results of spraying apples for the plum curculio, St. Joseph, Mo., 1909.*

Plat No.	Treatment.	Variety.	Tree No.	Total number of apples.	Total number of apples punctured.	Total number of punctures.	Percentage of sound apples.	Average percentage of sound apples.
I	Four applications Bordeaux mixture (4-4-50) plus 2 pounds arsenate of lead: May 16, June 9, July 9, and Aug. 6.	Ben Davis	1	1,747	966	2,443	44.70	
			2	1,624	660	1,355	59.35	
			3	1,579	844	2,012	46.54	
				4,950	2,470	5,810		50.10
II	One application. Drenched with arsenate of lead, 2 pounds to 50 gallons water, May 16.	do	1	2,769	1,909	5,054	31.05	
			2	3,019	1,749	4,236	42.06	
				5,788	3,658	9,290		36.80
III	Unsprayed	do	1	1,694	1,625	7,715	4.07	
			2	1,437	1,398	8,577	2.71	
			3	1,358	1,284	5,275	5.44	
				4,489	4,307	21,567		4.05

The records above given in spraying apple orchards for the curculio are assembled in Table CI, which indicates, in average percentages, the amount of uninjured fruit from each plat from the several localities, arranged according to the number of applications given. These experiments have extended over a period of several years and were made in various places, so that the results are not entirely comparable. Even when considering the results of individual experiments, a wide variation is seen in results from orchards which received practically the same treatment—for example, in the two orchards in Virginia sprayed during 1909.

TABLE CI.—*Summary of results in spraying apples for the plum curculio, in average percentages of sound fruit, various localities.*

Treatments.	Localities.							
	Illinois.	Anderson, Mo.	Westfield, N. Y.	North East, Pa.	Siloam Springs, Ark.	Crozet, Va.	Mount Jackson, Va.	St. Joseph, Mo.
1 application					86.34	73.93	57.90	36.80
2 applications				79.04				
3 applications							40.82	
4 applications			91.07			86.89		50.10
5 applications					82.88			
7 applications (Paris green)	45.47							
7 applications (arsenate of lead)	44.61	57.45						
7 applications (arsenite of lime)	47.80							
8 applications	44.52							
10 applications	44.74							
13 applications (home-made dust)		3.84						
13 applications (commercial dust)		22.15						
16 applications	62.08							
Unsprayed (check)	25.21	5.51	76.21	25.44	9.14	54.02	27.23	4.05

CONCLUSIONS.

The records above given of results of spraying apples for the control of the curculio indicate clearly that the injuries of the pest may be in all cases greatly reduced, although the degree of benefit varies widely. It is apparent that account must be taken of other factors, as the relative abundance of the insects as compared with the amount of fruit present on the trees. With a small fruit crop and abundance of curculios, the most thorough spraying will not serve to bring through a satisfactory amount of sound fruit, as will be noted in the results of experiments at St. Joseph, Mo. With a large crop of fruit and an abundance of insects, results will likewise be disappointing. If the curculios for any cause are scarce and there is a large fruit crop, injury is of course much less important. In other words, the degree of success in spraying varies with the abundance of the insects, and where the latter are numerous thorough treatments seem to fail to yield a desired freedom from injury. While spraying is undoubtedly a most important adjunct, and if persisted in from year to year may answer for its control, as its effects are cumulative, yet it is clear that other control measures should also be employed. In all cases which have come under our observations the insects have always been found most abundant in orchards which are in sod or are poorly cared for and allowed to grow up more or less in weeds and trash. Also orchards adjacent to woods always suffer severely, especially along the border. (Pl. XVI.) As opposed to this condition is the notably less injury in orchards kept free from weeds and trash. In such cases sprayings usually given for other orchard insects, as the codling moth, serve to keep this pest well under control. In

FIG. 1.—NATIVE PLUM THICKET IN THE SOUTH, ADJACENT TO PEACH ORCHARD. (ORIGINAL.)

FIG. 2.—WOODS AND THICKET ADJACENT TO PLUM ORCHARD, FURNISHING THE BEETLES WITH EXCELLENT HIBERNATION QUARTERS. (ORIGINAL.)

CONDITIONS FAVORING THE PLUM CURCULIO.

fact it may be said as a general statement that the curculio will never become seriously troublesome in apple orchards given the usual routine attention in cultivation, spraying, pruning, etc., now considered essential in successful fruit growing. Serious losses from the curculio are almost conclusive evidence of neglect, which is best and most quickly corrected by the adoption of proper orchard practice. The following schedule of spraying is recommended for apple orchards and should control the plum curculio as well as the numerous other insects mentioned. Where the curculio is excessively troublesome a treatment about midway between the third and fourth would probably be advantageous.

SCHEME FOR SPRAYING APPLE ORCHARDS.[1]

First treatment.—Spray with arsenate of lead in Bordeaux mixture or dilute lime-sulphur solution for apple scab when cluster buds are out, but before the blossoms open. This treatment is valuable against the bud moth, cankerworms, plum and apple curculios, tent caterpillar, etc.

Second treatment.—As soon as the petals have fallen, spray very thoroughly with arsenate of lead in Bordeaux mixture or dilute lime-sulphur solution so as to place a dose of poison in the calyx cup of each young apple. Larvæ of the codling moth, the principal cause of wormy apples, hatching some three or four weeks later, mostly enter the fruit at the blossom end, and are thus killed. This is the most important of all treatments for the codling moth and is valuable in destroying the lesser apple worm (*Enarmonia prunivora*), plum and apple curculios, cankerworms, tent caterpillars, etc.

Third treatment.—Three or four weeks after blossoms have fallen use arsenate of lead in Bordeaux mixture or dilute lime-sulphur solution, thoroughly coating the foliage and young fruit. This is valuable against the codling moth and affords further protection against the insects above mentioned.

Fourth treatment.—An additional application of the arsenical in a fungicide may be necessary, nine or ten weeks after the blossoms fall, for the second brood of the codling moth, and, in the Middle and Southern States especially, a fifth treatment is advisable two or three weeks later. In orchards not infested with the bud moth and cankerworms the first treatment may be omitted. The second, third, and fourth applications will suffice to give protection from most insect pests of the fruit and foliage, supplemented by the fifth for the territory indicated.

[1] Excellent results in control of the curculio and the codling moth have been obtained from a single application of an arsenical after the falling of the petals. The one-spray treatment is most likely to be ot value for varieties not subject to scab and bitter rot. The reader should obtain copies of reports on one-spray method, being Part VII of Bulletin 80 and Part II of Bulletin 115 of this bureau.

SPRAYING PEACHES WITH ARSENICALS.

Until within recent years comparatively little experimentation has been done with arsenicals for the control of the curculio on the peach. During the past five or six years, however, the subject has received attention at the hands of different investigators, and sufficient data have been accumulated to indicate about how much protection may be expected.

Paris green and London purple were undoubtedly early used on the peach, beginning with the first employment of these arsenicals against this insect. It was soon noted, however, that the foliage of peach was more sensitive than that of other deciduous fruits, and for this reason spraying of peaches seems not to have been practiced to any great extent. This foliage injury from arsenicals had been frequently commented upon and was pointed out by Dr. Forbes in 1888 and 1889, and also by Prof. Weed, who gave experience of a Marion County, Ohio, fruit grower, as follows:

> We accidentally stumbled over the fact that from 60 to 70 gallons of water to one-half pound of poison in solution was strong enough to fully check the curculio and all or more than the peach tree would stand. We destroyed a plum tree and several peach trees with our experiments, and know that 100 gallons to 1 pound of poison in solution is too strong for the foliage of some varieties of apples and that it will kill a peach or plum tree. My own opinion is that one-half pound of poison to 60 gallons is safe, and if applied at the time of the usual bloom of apple and the second time 10 days later will destroy the leaf-eating insects and the codling moths, but for plum and peach one-fourth pound to 40 gallons of water is strong enough and will, if applied twice, effectually check the ravages of the curculio without destroying the foliage.

Despite frequent serious defoliation of trees some peach growers undoubtedly continued the use of Paris green and London purple, especially in the Northern States. In the South comparatively little spraying was done, so far as available records indicate. The control of the curculio on peach was therefore largely limited to the practice of jarring, and this work was not very generally followed, the insect being allowed to continue its depredations unchecked. With the increase of commercial peach culture in certain of the Southern States, notably in Georgia, and in view of the favorable conditions for the multiplication of the pest, its injuries became especially serious, not only on account of the fruit destroyed by it, but by reason of the prevalence in that section of a serious fungous disease of the fruit at about ripening time, namely, the so-called brown-rot, which the work of this insect, by its punctures, greatly favored.

Considerable attention has been given during recent years to determining, if possible, ways in which Paris green and also copper fungicides may be safely used on the peach, notably by Messrs.

Gillette, Galloway, Woods, Fairchild, Sturgis, Baine, and Hedrick. It was found that the addition of lime to the Paris green or London purple spray greatly reduced its causticity, and the use of Paris green in this way was recommended for peach by Haywood, who says:

> In spraying peach trees, none of the Paris greens bought upon the market should be used without the addition of lime.
>
> For peach trees sprayed with the use of lime, the amount of soluble arsenic oxid allowable lies between 3 and 6 per cent, a fair average being $4\frac{1}{2}$ per cent.[1]

Nevertheless, even with the use of lime two or three applications of a Paris-green spray very generally resulted in defoliation of the trees, and in recommendations for the use of arsenicals on peaches this risk was very generally pointed out and understood by the majority of peach growers.

The development of arsenate of lead, a stable compound containing practically no free arsenic, it was thought would furnish an arsenical which might be used without injury on peaches. Experiments to determine its usefulness were at once begun by entomologists, and while it was noticeably less injurious than Paris green or London purple, yet in the South especially several applications, as deemed necessary for the control of the insect, caused a considerable amount of foliage to fall and often resulted in burning of the fruit. Arsenate of lead, however, was generally recommended for peach spraying by the manufacturers and also with caution by many entomologists and horticulturists. Not a few orchardists who tried the poison experienced disastrous results, whereas comparatively little injury was noted by others, who preferred to take the risk of foliage and fruit injury in preference to suffering the ravages of the curculio.

In a word, opinion was divided as to the advisability of spraying peaches with arsenate of lead, with perhaps on the whole a distinct prejudice against it.

In the course of the present curculio studies particular attention has been directed to the question of arsenical injury to peaches. During 1906 green arsenoid, Paris green, and arsenate of lead (both commercial and homemade) were tried on peaches according to a uniform plan of treatment in the Southern, Middle, and Northern States, in order to secure if possible comparative data from these regions. In all localities the green arsenoid and Paris green (3 applications each of 4 ounces to 50 gallons of lime water) proved injurious, defoliating trees almost completely. In northwestern Pennsylvania neither the commercial nor the homemade lead arsenate (3 applications at the rate each of 2 pounds to 50 gallons of lime water) caused noticeable injury. In Virginia the homemade lead

[1] Bul. 82, Bur. Chem., U. S. Dept. Agr., p. 32, 1904.

arsenate largely defoliated the trees and burned the fruit. There was, however, little foliage injury from the commercial arsenate of lead, though the fruit was injured and nearly all fell from the trees before ripening. In Georgia both forms of arsenate of lead defoliated the trees almost completely and injured the fruit to a serious extent, the homemade lead arsenate being the more injurious.

Also, during 1906, in Virginia, several other commercial brands of arsenate of lead were tried and no difference between them could be distinguished as to their effect on foliage and fruit. Arsenic sulphid in paste form, at the rate of 2 pounds to 50 gallons of lime water, was applied once and quickly defoliated the trees, killing the twigs and smaller branches, resulting finally in the death of several of the trees sprayed. During 1907 eight additional brands of arsenate of lead were tried in Virginia with from 1 to 4 applications in strength, varying from 1 to 3 pounds per 50 gallons of water. These were used with and without lime. Two applications at the rate of 2 pounds to 50 gallons of water, plus 2 or 3 pounds of stone lime, were found reasonably safe; and this treatment was adopted for recommendation to growers, although the risk of possible injury was pointed out.

In cooperation with the Bureau of Chemistry an inquiry was started in 1907 to determine if possible the reasons for injury to peach foliage from arsenate-of-lead sprays. The results of the work during 1907 and 1908 have been stated by Messrs. J. K. Haywood and C. C. McDonnell,[1] and conclusions were presented from the experiments in 1909. These studies have been extensive and are interesting as bearing on the causes of the decomposition of lead arsenate when sprayed on peach trees, resulting in injury to foliage and fruit. The idea of decomposition of the poison by the action of the carbon dioxid of the air was disproved by numerous tests, but it was found, in an examination of water used in spraying, that this contained a sufficient quantity of sodium chlorid (common salt) to decompose an appreciable quantity of the lead arsenate; and it was concluded that if certain salts commonly present in water were present in more than very small quantities they would exert a solvent action on the arsenate of lead. Concerning this matter Messrs. Haywood and McDonnell state:

(1) When applied with spring water (analysis of which has been given), some injury to foliage resulted, but it was not nearly so marked as in the preceding year, and a longer time elapsed before the injury was noticeable.

(2) When applied with distilled water very slight injury occurred, noticeably less than when the spring water was used.

(3) When applied with distilled water to which 10 grains per gallon of sodium chlorid had been added, rather serious injury resulted. When distilled water con-

[1] Bul. 131, Bur. Chem., U. S. Dept. Agr., p. 49, 1910.

taining 40 grains of sodium chlorid per gallon was used, the injury was very much increased, practically 50 per cent of the foliage being affected.

(4) When applied with distilled water containing 10 grains of sodium carbonate per gallon, injury was noticeable 14 days after the first application, and 7 days after the third application the trees were almost completely defoliated.

(5) Applied with distilled water containing 10 and 40 grains of sodium sulphate per gallon, some injury resulted, but this was not so marked as that produced in the presence of sodium chlorid.

In similar experiments where lime was added at the rate of 4 pounds to 50 gallons, injury to the foliage was almost entirely prevented.

In view of the above observations as to the possible importance of the water used in spraying, the Bureau of Entomology carried out spraying experiments in orchards in Georgia during 1910, employing 9 well-known brands of arsenate of lead, using these in ordinary well water and also in rain water, which it was thought would be entirely free from sodium chlorid and other salts. Three applications of the sprays were made, the milk of lime made from 2 pounds of good stone lime being added to the spray in each case. With all of the brands of arsenate of lead, the first two applications did no appreciable injury. The third application, given a month before ripening of the fruit, however, resulted in serious injury, which began to show after a rainy spell about a week after the applications. There appeared on the fruit brown sunken spots, which rapidly increased in size, causing the fruit to crack and drop to the ground until by picking time only 25 per cent still remained on the trees. This was barely fit for market purposes, having a dark red, almost black, appearance on the side exposed to the sun. These trees were 50 to 90 per cent defoliated. No difference in injury was to be detected from the use of rain water against ordinary well water.

These same brands of lead arsenate were used on trees alongside in the self-boiled lime-sulphur wash of the formula: Sulphur, 8 pounds; stone lime, 8 pounds; water to make 50 gallons. In these tests none of the fruit was burned enough to cause it to drop, all of it being merchantable. Some specimens, however, were so highly colored that they were placed in the second grade. About 20 per cent of the foliage on these lime-sulphur plats showed some injury, but none of it dropped. As regards the comparative injury from the different brands of arsenate of lead, very little difference could be detected, save in the case of one brand, which showed up about the same amount of injury as in the case of the other brands when applied in lime-sulphur wash. It was tested, however, on trees in another part of the orchard, as it was received too late to be included in the block where the balance of the lead arsenates were tried.

In addition to tests of lead arsenates, certain other arsenicals were tried to determine their effect on the foliage and fruit. The toxicity of these arsenicals was at the same time being determined in the

laboratory by feeding tests with the beetles. (See p. 186.) In each case the milk of lime from 2 pounds of stone lime was used to each 50 gallons of spray.

Arsenic sulphid (As_2S_2), $\frac{3}{4}$ pound to 50 gallons of water, was applied once April 29. By June 5 the plat treated with the poison in rain water showed injury to almost all of the leaves, with considerable foliage fallen, and this same condition prevailed on the plat treated with the poison in well water. On the lime-sulphur plat less than one-half as many leaves were injured and very few leaves had fallen.

Arsenic tersulphid (As_2S_3), 6 ounces to 50 gallons of water, applied April 13 and 24, showed by May 10 about 75 per cent of defoliation of all the trees on the 3 plats.

Red sulphid of arsenic (As_2S_2), 6 ounces to 50 gallons of water, applied April 13 and 29, showed on all plats by June 5 a condition similar to the arsenic tersulphid plat, though new foliage was coming out.

Sulpho-arsenate of soda, 6 ounces to 50 gallons of spray, showed by June 5 about 60 per cent of the foliage fallen, with those remaining badly burned and shot-holed. This condition was true on the 3 plats where the poison was used in well water, rain water, and the self-boiled lime-sulphur wash.

Arsenate of iron in paste form, 2 pounds to 50 gallons of water, applied April 29 and June 16, resulted in no foliage and fruit injury whatever throughout the season.

Arsenate of iron in powdered form, 1 pound to 50 gallons of water, applied to the trees April 13 and 29 and June 16, also resulted in no injury on any of the plats throughout the season.

Tests of the killing effect of arsenate of iron on the beetles in the laboratory indicated, however, that it is a very slow-killing agent; but it is probable that the beetles after first eating of the poison are rendered incapable of further important injury. Additional tests are planned with this poison on a commercial scale in orchards.

During 1908 and 1909 feeding tests with beetles and also with various caterpillars were made, using various compounds regarded as more or less toxic, with a view to their possible substitution for arsenicals for use on the peach. Among those tried were the following:

Black sulphid of antimony (Sb_2S_3).
Barium sulphid (BaS).
Barium carbonate ($BaCO_3$).
Copper sulpho-cyanid (Cu_4SCN_6).
Carbonate of lead ($PbCO_3$).
Lead oxid (PbO).
Zinc oxid (ZnO).
Zinc cyanid ($ZnCN$).

None of these, however, gave sufficient promise to warrant field tests.

From the foregoing it will be noted that severe injury has resulted from the use on peach of green arsenoid, Paris green, zinc sulphid, red sulphid of arsenic, tersulphid of arsenic, and sulpho-arsenate of soda. Injury from arsenate of lead has been variable, according to season, and especially depending upon the number of applications made. Two early treatments of the poison at the rate of not over 2 pounds to 50 gallons of water, with an equal or greater quantity of lime added, have on the whole caused comparatively little injury, although in some years injury has been fairly well marked. Three applications of lead arsenate in limewater, however, have rather uniformly been injurious. No important difference in the burning effect of the different brands of arsenate of lead has been detected; and according to the tests made in 1910 in the comparison of rain water and well water no difference between them was discernible.

The time between the applications of the poison and the appearance of injury to the foliage varies, depending upon the arsenical in question. Thus Paris green, green arsenoid, and sulphid of arsenic promptly show a shot-holing and yellowing of the leaves, which later drop more or less completely. (See Pl. XVII, figs. 1–6.) The injury resulting from lead arsenate is about the same, only it is slower to appear. In the case of two applications dropping of the leaves may be so gradual as not to attract attention and may be largely compensated for by the production of new foliage. A third application, however, is generally followed by a decided and prompt dropping of the foliage, usually within 10 days or 2 weeks, leaving the branches more or less bare and the fruit exposed to the sun. Arsenate of lead also produces a notable reddening of the fruit, though this reddening is due in part to an increased amount of sunshine following the thinning of the leaves. This increased coloring is the subject of common remark by growers, and if but one or two applications of the poison have been made is not so pronounced as to detract from the appearance of the fruit. A third application, however, very generally results in an intense dark-red coloring and the associated changes brought about very often result in brown depressed areas of variable extent and a cracking on the sunny side of the peach. Fruit so injured is worthless and mostly drops before ripening time. (See Pl. XVIII, fig. 1.)

For the proper control of the curculio on peach three or four applications of the poison would be desirable. However, in view of the injury resulting from more than two treatments, recommendations have been limited to two timely applications of the poison, and always with the addition of limewater. This treatment gave a considerable degree of protection and has recently come into a rather extended use by peach growers.

SOME RESULTS OF SPRAYING PEACHES FOR THE CURCULIO.

In the following tables some results of spraying peaches for the curculio are presented. The benefits are seen to vary from season to season, as in the case of the apple, depending upon the abundance of the insects. On account of the difficulty of taking note of punctures in the fuzzy peaches, the results are based on records of actual infestation of fruit by larvæ or indications of the presence of the latter. The results obtained by this metnod of computation on the different plats should be entirely comparable. Examinations were made of all drop fruit during the season, as well as of the ripe fruit at picking time. One of the most important results in spraying for the curculio is the reduction of brown rot. The punctures of the curculio in the fruit form an easy point of infection, and very notable benefits in the reduction of brown rot may be observed in orchards sprayed only for the curculio.

In Table CII are given results of spraying of peaches in 1906 on the Arlington Farm, Va. The orchard used contained about 500 trees and was an isolated one, but adjacent to a thick growth of young trees and bushes. Not all of the trees were treated, each plat containing some 50 trees. The applications were made on the dates indicated in the table. It was also thought desirable to determine the possible benefit of spraying the trees heavily with simply lime-water, inasmuch as this method of curculio control has been somewhat exploited.

TABLE CII.—*Results of spraying peaches for the plum curculio, Arlington Farm, Va., 1906.*

Plat No.	Treatment.	Tree No.	Fruit from ground.		Fruit from tree.		Total number of fruit.	Total number of fruit infested.	Percentage of sound fruit.	Average percentage of sound fruit.
			To-tal.	In-fest-ed.	To-tal.	In-fest-ed.				
I	Three applications, 2 pounds arsenate of lead to 50 gallons water, plus 3 pounds stone lime: Apr. 27; May 8 and 20.	1	773	7	444	14	1,217	21	98.27	....
		2	1,067	35	674	7	1,741	42	97.58	....
		3	646	23	220	8	866	31	96.42	....
		4	743	4	350	7	1,093	11	98.99	....
		5	423	74	179	9	602	83	86.21	....
			3,652	143	1,867	45	5,519	188	....	96.59
II	Three applications, whitewash lime 15 pounds to 50 gallons water: Apr. 27; May 8 and 20.	1	393	37	83	....	476	37	92.22	....
		2	309	56	254	12	563	68	87.90	....
		3	419	118	136	18	555	136	75.49	....
		4	554	79	345	30	899	109	87.87	....
		5	548	78	250	9	798	87	89.09	....
			2,223	368	1,068	69	3,291	437	....	86.72
III	Untreated	1	374	108	....	....	374	108	71.12	....
		2	243	64	336	22	579	86	85.14	....
		3	201	47	....	....	201	47	76.61	....
		4	440	140	118	11	558	151	72.93	....
		5	830	234	70	2	900	236	73.77	....
			2,088	593	524	35	2,612	628	....	75.96

The curculio was not especially abundant in this orchard during 1906; as shown by the condition of the check, about 25 per cent of

EFFECT OF ARSENICAL SPRAYS ON PEACH FOLIAGE, ARLINGTON FARM, VA.

Fig. 1.—Unsprayed or check tree. Fig. 2.—Tree sprayed once with commercial arsenate of lead. Fig. 3.—Tree sprayed once with homemade arsenate of lead. Fig. 4.—Tree sprayed once with Paris green. Fig. 5.—Tree sprayed once with green arsenoid. Fig. 6.—Tree sprayed once with arsenic sulphid. (Original.)

FIG. 1.—ELBERTA PEACH SPRAYED THREE TIMES WITH ARSENATE OF LEAD, SHOWING BURNING AND CRACKING EFFECTS OF THE POISON. (ORIGINAL.)

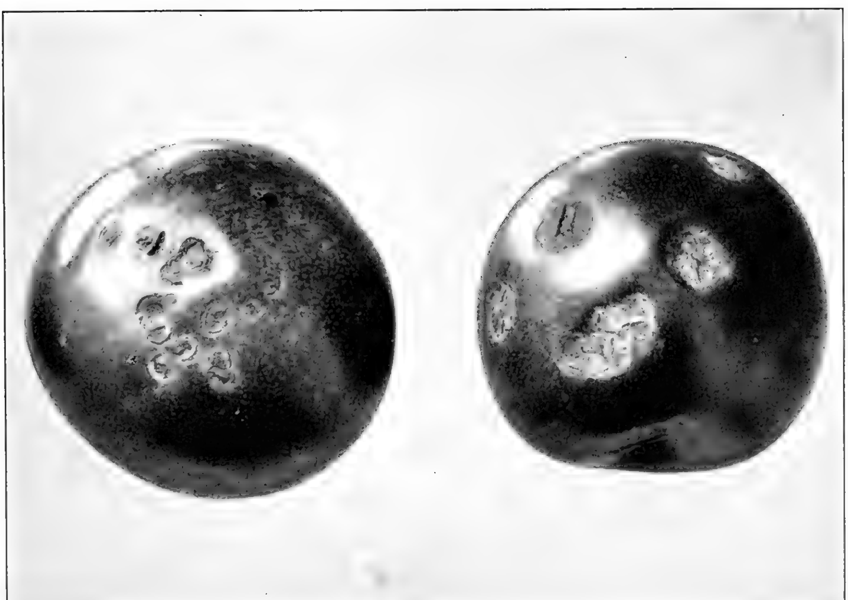


FIG. 2.—JAPANESE PLUMS, SHOWING BURNING FROM ONE APPLICATION OF ARSENATE OF LEAD. (ORIGINAL.)

ARSENICAL INJURY TO FRUIT

the fruit was infested. Nevertheless, the results show a certain benefit, there being a gain in uninjured fruit on the plat treated with arsenate of lead of 20.63 per cent, and on Plat II, treated with lime, of 10.76 per cent.

Results obtained also in 1906 at Myrtle, Ga., are shown in Table CIII. The trees treated were located in an 8-acre block of the Georgia Belle variety, composing a 200-acre orchard. The treated area, however, was on one side of the orchard and fairly well separated from the main body of the trees. Conditions for the curculio were here ideal on account of adjacent woods, and the presence here and there through the orchard of terraces which had become overgrown with bushes, weeds, etc. Each plat comprised 50 trees. The dates and character of applications are shown in the table, as well as the number of trees on which records were taken.

The average percentage of sound fruit on the untreated trees was 67.59 per cent. As compared with this injury there is a gain in sound fruit on Plat I, sprayed with arsenate of lead, of 21.04 per cent, and on Plat II, sprayed with lime, of 2.20 per cent.

Results of spraying peaches at Mayfield, Ga., for the curculio in 1908 are shown in Table CIV. This work was carried out by the office of the Georgia State entomologist according to a plan furnished by this bureau. Each plat contained 60 trees of the Elberta variety, and while a sufficient number of trees was not used for making counts of the fruit, the results are nevertheless significant.

TABLE CIII.—*Results of spraying Georgia Belle peaches for the plum curculio, Myrtle, Ga., 1906.*

Plat No.	Treatment.	Tree No.	Fruit from ground.		Fruit from tree.		Total number of fruits.	Total number of fruits infested.	Percentage of sound fruit.	Average percentage of sound fruit.
			Total.	Infested.	Total.	Infested.				
		1	18	4	121	27	139	31	77.69	....
		2	28	6	171	4	199	10	94.97	....
		3	47	7	144	4	191	11	94.24	....
		4	39	13	135	9	174	22	87.35	....
I.....	Three applications homemade arsenate of lead 2 pounds to 50 gallons of water plus 3 pounds stone lime: Apr. 10, 21, and 30.	5	33	10	180	5	213	15	92.95	....
		6	10	4	81	5	91	9	90.10	....
		7	38	22	213	8	251	30	88.04	....
		8	14	3	80	5	94	8	91.48	....
		9	42	16	266	16	308	32	89.61	....
		10	23	11	92	15	115	26	77.38	....
		11	14	4	48	7	62	11	82.25	....
		12	27	14	134	8	161	22	86.33	....
			333	114	1,665	113	1,998	227	....	88.63
		1	2	1	24	2	26	3	88.46	....
		2	10	4	32	12	42	16	61.90	....
		3	66	10	77	9	143	19	86.71	....
		4	10	6	29	3	39	9	76.92	....
II....	Three applications of whitewash, 15 pounds lime to 50 gallons water (no arsenical): Apr. 3, 13, and 21.	5	33	20	69	16	102	36	65.70	....
		6	17	4	59	13	76	17	77.63	....
		7	28	16	63	23	91	39	57.14	....
		8	27	15	144	35	171	50	70.76	....
		9	22	12	46	9	68	21	69.11	....
		10	7	1	16	6	23	7	69.56	....
		11	27	13	31	18	58	31	46.55	....
		12	50	37	220	50	270	87	67.74	....
			299	139	810	196	1,109	335	....	69.79

TABLE CIII.—*Results of spraying Georgia Belle peaches for the plum curculio, Myrtle, Ga., 1906*—Continued.

Plat No.	Treatment.	Tree No.	Fruit from grounds. Total.	Fruit from grounds. Infested.	Fruit from tree. Total.	Fruit from tree. Infested.	Total number of fruits.	Total number of fruits infested.	Percentage of sound fruit.	Average percentage of sound fruit.
III...	Untreated..........	1	34	14	42	18	76	32	57.89	....
		2	29	22	25	17	54	39	27.77	....
		3	70	33	185	28	255	61	76.08	....
		4	69	33	224	52	293	85	70.98	....
		5	81	48	187	48	268	96	64.17	....
		6	28	16	98	26	126	42	66.66	....
		7	18	14	46	17	64	31	51.56	....
		8	14	11	75	20	89	31	65.16	....
		9	22	12	58	14	80	26	67.50	....
		10	16	6	80	6	96	12	87.50	....
		11	21	18	29	7	50	25	50.00	....
		12	17	9	75	11	92	20	78.26	....
			419	236	1,124	264	1,543	500	....	67.59

TABLE CIV.—*Results of spraying Elberta peaches for the plum curculio, Mayfield, Ga., 1908.*

Plat No.	Treatment.	Tree No.	Fruit from ground. Total.	Fruit from ground. Infested.	Fruit from tree. Total.	Fruit from tree. Infested.	Total number of fruits.	Total number of fruits infested.	Percentage of sound fruit.	Average percentage of sound fruit.
I.....	Four applications, 2 pounds arsenate of lead plus 3 pounds stone lime per 50 gallons of water: Apr. 2, 11, 17, and 25.	1	156	14	336	137	492	151	69.31	....
		2	100	11	110	32	210	43	79.53	....
		3	194	19	437	127	631	146	76.86	....
			450	44	883	296	1,333	340	....	74.41
II....	Three applications, 2 pounds arsenate of lead plus 3 pounds stone lime per 50 gallons of water: Apr. 2, 11, and 17.	1	98	12	322	137	420	149	64.52	....
		2	188	9	213	107	301	116	61.46	....
		3	228	18	361	140	589	158	73.18	....
		4	296	34	331	154	627	188	70.02	....
			810	73	1,227	538	2,037	611	....	70.00
III...	Two applications, 2 pounds arsenate of lead plus 3 pounds stone lime per 50 gallons water: Apr. 2 and 11.	1	136	46	184	97	320	143	55.31	....
		2	135	16	299	38	434	54	87.56	....
		3	163	26	336	132	499	158	68.34	....
		4	61	3	145	45	206	48	76.70	....
			495	91	964	312	1,459	403	....	72.30
IV...	Untreated..........	1	119	87	75	64	194	151	22.17	....
		2	86	59	10	9	96	68	29.17	....
		3	133	39	278	197	411	236	42.58	....
		4	85	61	125	122	210	183	12.86	....
		5	134	82	143	126	277	208	24.91	....
			557	328	631	518	1,188	846	....	28.78

It will be noticed that on the unsprayed block only 28.78 per cent of the fruit was uninfested. Plat I, which received 4 applications of arsenate of lead, shows a gain in sound fruit of 45.63 per cent. Plat II, which received 3 applications, of 41.22 per cent, and Plat III, receiving 2 applications, a gain of 43.52 per cent. According to the notes accompanying this experiment very serious injury followed the

4 applications given Plat I, and the injury to Plat III was also so severe as to render unsafe such a number of applications.

Table CV gives results of spraying Elberta peaches for the curculio at Baldwin, Ga., in 1910. (See Pl. XIX.) These plats contained some 200 trees each and counts were made of fruit produced throughout the season on 12 trees from each plat. Two applications of arsenate of lead were made, the first in water and the second in the self-boiled lime-sulphur wash (see p. 212). At the time of the first application, April 7–8, the blossoms of the trees had just fallen. The unsprayed block (Plat II) yielded 56.85 per cent of sound fruit as compared with 89.85 per cent of sound fruit from the sprayed block, a gain of 33 per cent.

TABLE CV.—*Results of spraying Elberta peaches for the plum curculio, Baldwin, Ga., 1910.*

Plat No.	Treatment.	Tree No.	Fruit from ground.		Fruit from tree.		Total number of fruits.	Total number of fruits infested.	Percentage of sound fruit.	Average percentage of sound fruit.
			Total.	Infested.	Total.	Infested.				
I	First application Apr. 7–8, arsenate of lead 2 pounds to 50 gallons water; second application, 2 pounds arsenate lead in self-boiled lime-sulphur wash (8–8–50), Apr. 27–28; third application, lime-sulphur wash only (8–8–50), June 17–18.	1	447	7	589	26	1,036	33	96.81	......
		2	119	8	465	45	584	53	90.92	......
		3	177	10	388	65	565	75	86.72	......
		4	363	24	606	76	969	100	88.63	......
		5	161	10	335	61	496	71	85.68	......
		6	96	12	409	26	505	38	92.47	......
		7	99	2	358	38	457	40	91.23	......
		8	222	22	293	33	515	55	89.32	......
		9	702	25	412	123	1,114	148	86.71	......
		10	224	6	476	83	700	89	87.28	......
		11	68	7	410	50	478	57	88.07	......
		12	348	17	456	58	804	75	90.67	......
			3,026	150	5,197	684	8,223	834	......	89.85
II	Untreated	1	188	115	324	178	512	293	42.77	......
		2	187	83	385	132	572	215	62.41	......
		3	147	85	280	155	427	240	43.79	......
		4	839	114	648	239	1,487	353	76.26	......
		5	76	56	129	79	205	135	34.14	......
		6	605	165	471	189	1,076	354	67.10	......
		7	192	71	177	94	369	165	55.28	......
		8	318	55	299	147	617	202	67.26	......
		9	68	67	388	251	456	318	30.26	......
		10	143	67	176	137	319	204	36.05	......
		11	214	110	347	231	561	341	39.21	......
		12	274	100	283	168	557	268	51.88	......
			3,251	1,088	3,907	2,000	7,158	3,088	......	56.85

The recent development, by Prof. W. M. Scott of the Bureau of Plant Industry of this department, of the self-boiled lime-sulphur wash as a fungicide for the control of brown rot and the scab of peach at once gave an enormous impetus to peach spraying. The desirability of combining arsenate of lead with the self-boiled lime-sulphur wash led to many tests to determine its practicability. Such a combination, while resulting in important chemical changes, has in actual practice resulted in a spray which appears to be perfectly safe to peach foliage and fruit. Experience during the past 3 years

with this combined spray on peaches under varying climatic conditions seems to leave no doubt that by this combination the injurious properties of the arsenate of lead, as when used alone, are so reduced as to be practically negligible. This probably results from the excess of lime in the self-boiled wash. In Circular 120 of this bureau, published in the spring of 1910, a schedule of applications for this combined spray was given, including 2 applications of arsenate of lead with an additional one of the lime-sulphur wash alone. This schedule was followed by many orchardists in the South and a large aggregate of trees was thus treated. The results have been uniformly satisfactory, so far as controlling the curculio and the diseases are concerned, and without noticeable injury to the foliage and fruit above referred to. It may therefore be assumed that a satisfactory combined spray for the insect and the brown rot and scab of the peach has been established, as has so long been in use on other deciduous fruits.

Results of further experiments with this combined spray for the curculio, brown rot, and scab during 1910 have been given in Farmers' Bulletin 440, fully confirming previous results as to its great usefulness for the practical control of these three troubles. It is practically certain that its use will be equally effective in preventing losses to other stone fruits, as plums, cherries, apricots, etc. Directions for making the self-boiled lime-sulphur wash and arsenate of lead spray, with a schedule of treatments for peaches, are quoted from the bulletin above referred to.

DIRECTIONS FOR THE PREPARATION OF SELF-BOILED LIME-SULPHUR WASH.

The standard self-boiled lime-sulphur mixture is composed of 8 pounds of fresh stone lime and 8 pounds of sulphur to 50 gallons of water. In mild cases of brown rot and scab a weaker mixture containing 6 pounds of each ingredient to 50 gallons of water may be used with satisfactory results. The materials cost so little, however, that one should not economize in this direction where a valuable fruit crop is at stake. Any finely powdered sulphur (flowers, flour, or "commercial ground" sulphur) may be used in the preparation of the mixture.

In order to secure the best action from the lime, the mixture should be prepared in rather large quantities, at least enough for 200 gallons of spray, using 32 pounds of lime and 32 pounds of sulphur. The lime should be placed in a barrel and enough water (about 6 gallons) poured on to almost cover it. As soon as the lime begins to slake the sulphur should be added, after first running it through a sieve to break up the lumps, if any are present. The mixture should be constantly stirred and more water (3 or 4 gallons) added

FIG. 1.—GASOLINE POWER OUTFIT IN OPERATION. (ORIGINAL.)

FIG. 2.—DETERMINING RESULTS OF SPRAYING, EACH PEACH BEING CUT OPEN. (ORIGINAL.)

FIELD EXPERIMENTS IN GEORGIA FOR CONTROL OF PLUM CURCULIO AND PEACH DISEASES.

as needed to form at first a thick paste and then gradually a thin paste. The lime will supply enough heat to boil the mixture several minutes. As soon as it is well slaked water should be added to cool the mixture and prevent further cooking. It is then ready to be strained into the spray tank, diluted, and applied.

The stage at which cold water should be poured on to stop the cooking varies with different limes. Some limes are so sluggish in slaking that it is difficult to obtain enough heat from them to cook the mixture at all, while other limes become intensely hot on slaking, and care must be taken not to allow the boiling to proceed too far. If the mixture is allowed to remain hot for 15 or 20 minutes after the slaking is completed, the sulphur gradually goes into solution, combining with the lime to form sulphids, which are injurious to peach foliage. It is therefore very important, especially with hot lime, to cool the mixture quickly by adding a few buckets of water as soon as the lumps of lime have slaked down. The intense heat, violent boiling, and constant stirring result in a uniform mixture of finely divided sulphur and lime, with only a very small percentage of the sulphur in solution. The mixture should be strained to take out the coarse particles of lime, but the sulphur should be carefully worked through the strainer.

DIRECTIONS FOR USING ARSENATE OF LEAD.

Many experiments have shown that well-made arsenate of lead is much the safest of all arsenicals at present available for use on the peach. Arsenate of lead is to be found on the market both as a powder and as a putty-like paste, which latter must be worked free in water before it is added to the lime-sulphur mixture. The paste form of the poison is largely used at the rate of about 2 pounds to each 50 gallons of the lime-sulphur wash and is added, after it has been well worked free in water, to the lime-sulphur spray previously prepared. As there are numerous brands of arsenate of lead upon the market, the grower should be careful to purchase from reliable firms. A decided change in color will result when the arsenate of lead is added to the lime-sulphur mixture, due to certain chemical changes which, in the experience of the writers, do not injuriously affect the fungicidal and insecticidal properties of the spray or result in important injury to the foliage.

In large spraying operations it will be more convenient to prepare in advance a stock mixture of arsenate of lead, as follows: Place 100 pounds of arsenate of lead in a barrel, with sufficient water to work into a thin paste, diluting finally with water to exactly 25 gallons. When thoroughly stirred, each gallon of the stock solution will thus contain 4 pounds of arsenate of lead, the amount necessary for 100

gallons of spray. In smaller spraying operations the proper quantity of arsenate of lead may be weighed out as needed, and thinned with water. In all cases the arsenate of lead solution should be strained before or as it is poured into the spray tank. The necessary care should be exercised to keep the poison out of the reach of domestic and other animals. Powdered arsenate of lead is used at about one-half the strength of the paste form.

SCHEDULE OF APPLICATIONS.

Most of the peach orchards in the eastern half of the United States should be given the combined treatment for brown-rot, scab, and curculio. This is particularly true of the southern orchards, where all these troubles are prevalent. In some of the more northern orchards the curculio is not very troublesome, but as a rule it will probably pay to add the arsenate of lead in at least the first lime-sulphur application.

The self-boiled lime-sulphur mixture referred to in the following outlines of treatment should be made of a strength of 8 pounds of lime and 8 pounds of sulphur to each 50 gallons of water, and the arsenate of lead should be used at the rate of 2 pounds to each 50 gallons of the mixture or of water. When the poison is used in water there should be added the milk of lime made from slaking 2 to 3 pounds of good stone lime. When used in the lime-sulphur mixture additional lime will not be necessary.

Midseason varieties.—The midseason varieties of peaches, such as Reeves, Belle, Early Crawford, Elberta, Late Crawford, Chairs, Fox, and Beers Smock, should be sprayed as follows:

(1) With arsenate of lead alone, about 10 days after the petals fall (Pl. XX), or at the time the calyxes are shedding.

(2) With self-boiled lime-sulphur and arsenate of lead, two weeks later, or four to five weeks after the petals have been shed.

(3) With self-boiled lime-sulphur alone, four to five weeks before the fruit ripens.

Late varieties.—The Salway, Heath, Bilyeu, and varieties with a similar ripening period should be given the same treatment prescribed for midseason varieties, with an additional treatment of self-boiled lime-sulphur alone, to be applied three or four weeks after the second application.

Early varieties.—The Greensboro, Carman, Hiley, Mountain Rose, and varieties having the same ripening period should receive the first and second applications prescribed for midseason varieties.

Where the curculio is not particularly bad, as in Connecticut, western New York, and Michigan, the first treatment, which is for this insect only, may be omitted. Also for numerous orchards throughout the Middle States where the insect, especially in the younger orchards, is not yet very troublesome, orchardists should

SIZE OF PEACHES AT TIME OF FIRST SPRAYING WITH ARSENATE OF LEAD, SHOWING ON THE LEFT THE EARLIEST AND ON THE RIGHT THE LATEST STAGES IN DEVELOPMENT WHEN THIS TREATMENT SHOULD BE GIVEN. (ORIGINAL.)

use their judgment as to whether the first application may be safely omitted. Where peach scab is the chief trouble, and brown-rot and curculio are of only minor importance, as may be the case in some of the Allegheny Mountain districts, satisfactory results may be had from two applications, namely, the first with self-boiled lime-sulphur and arsenate of lead four to five weeks after the petals fall, and the second treatment of the above schedule with self-boiled lime-sulphur alone three to four weeks later. These two treatments, if thoroughly applied, will control the scab and brown-rot, especially on the early and midseason varieties, and will materially reduce curculio injuries. Even one application of the combined spray made about five weeks after the petals fall would pay well, although this is recommended only for conditions where it is not feasible to do more.

SPRAYING PLUMS AND CHERRIES.

The first important tests of arsenicals in the control of the curculio were made on plums and cherries. In 1887 Mr. W. B. Alwood, working under the direction of the entomologist of this department, made some limited tests on the grounds of the Ohio Agricultural Experiment Station, spraying Green Gage plum trees with Paris green at the rate of 1 pound to 50 gallons of water. Fully 50 per cent of the foliage and much of the fruit fell from the trees as a result of the treatment. No definite conclusions were drawn from the experiment. May 17 of the same year 17 cherry trees were also sprayed with Paris green, 1 pound to 50 gallons of water, and the results in this instance also were not fully determined.

During the same year Prof. A. J. Cook in Michigan sprayed 4 plum trees May 18 with Paris green at the rate of 1 tablespoonful to 6 gallons of water. No trees were kept for comparison, and no definite conclusions were thus to be drawn. During 1888 Prof. H. Osborn, then an agent of the Division of Entomology, carried out in Iowa some thorough spraying experiments, using 11 plum trees of several varieties, leaving 10 trees unsprayed as a check. London purple was used at the rate of one-half pound to 100 gallons, applications being made June 1 and 11. Concerning results, Prof. Osborn states:

> Combining the entire count of all varieties, and we have for the sprayed trees a final of 32.48 per cent punctured, or stung, and 5.71 per cent containing larvæ, against a final of 41.86 per cent stung and 10.39 per cent containing larvæ for the check trees.

During the same year Prof. Weed in Ohio began a series of tests of arsenicals on cherry and plum, which were continued during 1889 and 1890, during which latter year the work was carried out on a commercial basis in a plum orchard of 900 trees in the fruit districts along the south shore of Lake Erie. These careful experiments of Prof. Weed clearly showed that a considerable benefit from spraying was to be derived and were altogether the most extensive and complete heretofore presented.

In Bulletin 9 of the Iowa Agricultural Experiment Station, page 383 (1890), Prof. Gillette gives results of experiments on plums with London purple on the plum curculio and plum gouger. The poison was applied with a hand pump to 23 trees at the rate of 1 pound to 120 gallons May 4 and 11. The leaves were badly burned. After May 25 all drop fruit on 5 trees each of the sprayed and unsprayed blocks was examined. A total of 21,000 plums was examined, and a benefit was determined of 1.1 per cent in favor of spraying.

SOME RESULTS OF SPRAYING PLUMS.

At Fort Valley, Ga., during 1905 Mr. Beattie carried out some spraying tests on Japanese plums. The plats were, however, small and there was considerable overflow from the surrounding unsprayed trees. Plats were laid off, extending across three varieties, namely, Wickson, Red June, and Satsuma, in which order the varieties are given in the table. The entire crop throughout the season from three trees of each variety was counted with the exception of Plat I, where only 2 trees were used. Plats received from 1 to 3 applications of arsenate of lead in water, without addition of lime. According to Mr. Beattie's notes practically no injury resulted to the foliage from the sprays. The results are given in Table CVI.

TABLE CVI.—*Results of spraying Japan plums for the plum curculio, Fort Valley, Ga., 1905.*

Plat No.	Treatment.	Tree No.	Fruit from ground.				Fruit from tree.				Total fruit punctured.	Total fruit infested.	Total number sound fruit.	Total number fruit.	Average percentage sound fruit.	Percentage of ripe fruit punctured.
			Punctured.	Infested.	Sound.	Total.	Punctured.	Infested.	Sound.	Total.						
I.....	One application, arsenate of lead, 2 pounds to 50 gallons water, Mar. 19.	1	52	44	2	54	152	37	26	178	204	81	28	232	......	......
		2	236	213	114	350	60	4	300	360	296	217	414	710	......	......
			288	257	116	404	212	41	326	538	500	298	442	942	46.92	39.41
II....	Two applications arsenate of lead, 2 pounds to 50 gallons water, Mar. 19 and Apr. 20.	1	255	211	71	326	430	28	527	957	685	239	598	1,283	......	......
		2	372	345	38	410	31	11	35	66	403	356	73	476	......	......
		3	210	172	32	242	73	15	200	273	283	187	232	515	......	......
			837	728	141	978	534	54	762	1,296	1,371	782	903	2,274	39.70	41.20
III...	Three applications arsenate of lead, 2 pounds to 50 gallons water, Apr. 4 and 20, May 4.	1	88	69	72	160	90	25	270	360	178	94	342	520	......	......
		2	153	138	65	218	90	30	194	284	243	168	259	502	......	......
		3	108	92	53	161	72	8	313	385	180	100	366	546	......	......
			349	299	190	539	252	63	777	1,029	601	362	967	1,568	61.67	24.48
IV...	Unsprayed..........	1	68	45	31	99	40	9	35	75	108	54	66	174	......	......
		2	105	87	30	135	105	17	91	196	210	104	121	331	......	......
		3	72	58	10	82	118	36	6	124	190	94	16	206	......	......
			245	190	71	316	263	62	132	395	508	252	203	711	28.55	66.58

Curculio injury on all of the plats was severe. On the check there was only 28.55 per cent of fruit free from punctures and infestation. On the plat sprayed 3 times, 61.67 per cent of the plums were sound, a gain in sound fruit over the check of 33.12 per cent. Two applications gave a gain of 11.15 per cent and the single treatment showed an increase over the check of 18.37 per cent, a difference doubtless due to location. A more exact idea of the commercial benefits of spraying, however, may be had by a consideration of the relative amount of ripe fruit at picking time showing the punctures of the insect, as being more or less deformed and unsalable, for it will be understood that not all ripe fruit showing punctures is unsalable. On the check plat (IV) of the ripe fruit at picking time 66.58 per cent were punctured, as against 24.48 per cent on Plat II, receiving 3 applications. Plats I and II show about the same amount of puncturing on the ripe fruit, namely, 39.41 and 41.20 per cent, respectively.

During 1906, at North East, Pa., an orchard of about two hundred 16-year old plum (York State prune) trees were sprayed by Mr. Johnson, using Bordeaux mixture plus 3 pounds arsenate of lead. Through an error only one tree was left unsprayed for comparison. All of the fruit throughout the season was carefully examined from this tree and an adjacent unsprayed tree, and the results are shown in Table CVII. Previous to this season the owner had followed the jarring method, but by reason of the favorable results spraying was subsequently followed.

This same orchard was sprayed during the following year by Mr. Johnson, and results taken on five sprayed and five unsprayed trees are shown also in the table.

TABLE CVII.—*Results of spraying York State prunes for the plum curculio during the seasons 1906 and 1907, North East, Pa.*

1906.

Trees.	Treatment.	Fruit from ground. Punctured.	Fruit from ground. Infested.	Fruit from ground. Sound.	Fruit from ground. Total.	Fruit from tree. Punctured.	Fruit from tree. Infested.	Fruit from tree. Sound.	Fruit from tree. Total.	Total fruit punctured.	Total fruit infested.	Total sound fruit.	Total number fruit.	Percentage sound fruit.
1	Three treatments, Bordeaux mixture (4-4-50) plus 3 pounds arsenate of lead: May 25, June 7 and 19.	448	393	1,207	1,655	69	0	1,640	1,709	517	393	2,847	3,364	84.63
	One untreated.....	1,621	1,446	532	2,153	272	0	470	742	1,893	1,446	1,002	2,895	34.61

1907.

Trees.	Treatment.	Fruit from ground. Punctured.	Fruit from ground. Infested.	Fruit from ground. Sound.	Fruit from ground. Total.	Fruit from tree. Punctured.	Fruit from tree. Infested.	Fruit from tree. Sound.	Fruit from tree. Total.	Total fruit punctured.	Total fruit infested.	Total sound fruit.	Total number fruit.	Percentage sound fruit.
5	Two applications, Bordeaux mixture (4-4-50) plus 3 pounds arsenate of lead: June 8 and July 3.	435	344	6,933	7,368	14	0	9,559	9,573	449	344	16,492	16,941	97.35
	Five untreated.....	581	490	7,481	8,062	57	0	8,153	8,210	638	490	15,634	16,272	96.08

During 1906 there was a gain in sound fruit on the sprayed trees of 50.02 per cent as compared with the check of 50.01 per cent. The difference the following year, however, was small, 1.27 per cent, as the insects were comparatively scarce, no doubt following their practical extermination in the orchard the year previous.

Extensive plum-spraying experiments were begun at Barnesville, Ga., in 1910. The work, however, was stopped by the loss of practically all of the fruit from the effects of a heavy wind storm.

RESULTS OF SPRAYING CHERRIES.

A block of Montmorency cherry trees at North East, Pa., was sprayed June 11 with 3 pounds of arsenate of lead to 50 gallons of water plus 3 pounds of stone lime. Another block received an additional application June 25, while a third block (4 rows through center of orchard) was left unsprayed. When fruit was gathered, July 18, three trees on the first-mentioned plat gave a total of 16 wormy cherries and 43½ pounds of sound fruit. The same number of trees on the second block, having 2 applications, gave 10 wormy cherries and 53 pounds of sound fruit. The 3 trees on the check plat gave 74 wormy cherries and only 16 pounds of sound fruit. The trees were chosen as nearly alike as possible and the results may thus be fairly compared. As compared with the check, the plat treated twice shows an increase in sound fruit of 37 pounds and from the plat sprayed once a gain of 27.5 pounds.

More data are needed to show the protection from curculio which will follow spraying plums and cherries, though this will without doubt be quite as marked as with peaches. The same spraying schedule indicated for early peaches will be suitable for plums and cherries, and the arsenical should be used in the self-boiled lime-sulphur wash.

ECONOMIC BIBLIOGRAPHY.[1]

1736–7. Collinson and Bartram.—Darlington's Memorials of Bartram and Marshall, p. 85.

Remedy for insect that annoys plums, apricots, and nectarines.

Id.—p. 93.

An account of the destruction by an insect of plums and nectarines.

Id.—p. 120.

Advice against the planting of sloes, as they are "liable to be bitten with the same insect as the rest of our stone fruits."

1749. Kalm, Peter.—Travels into North America.<Foster's English Translation, 2nd Edition, London, 1772, p. 44, vol. 2.

Under date of May 18, 1849, writing of New Jersey: "The grass in the meadows is likewise consumed by a kind of worms, and other species cause the plums to drop, before they are half ripe."

1302. Burton, Benj. Smith, M. D.—On the Natural History of North America. Letter to M. Lacépède of Paris. Philadelphia, October 31, 1802.<In Philosoph. Mag., vol. 22, p. 204, 1805.

"The unripe fruit of the peach is greatly injured by a species of curculio; but the insects most pernicious to this tree are two Lepidopterous insects of the genus Xygæna Fabr. These while in the larval state destroy the bark of the root." Footnote, p. 208.

1804. Tilton, James.—Curculio.<Willich's Domestic Encyclopædia, vol. 3, p. 116, 1804. 2. Extr. Papers on Agr., vol. 2, pp. 15–19, 1809.

Probably earliest extended account of the plum curculio.

1806. Melsheimer, Fred. Val.—Catalogue of Insects of Pennsylvania, p. 28, No. 589.

Lists as *Curculio persicæ*, and states, lives in *Malus persica*, the larva under bark.

1807. Olivier.—Histoire Naturelle des Insectes, vol. 5, p. 19, 1807.

1807. Tilton, James.—Memoirs of the Philadelphia Society for Promoting Agriculture, vol. 1, pp. 34–38, Appendix.

Several correct facts about the feeding habits of the curculio, its mode of propagation, and points in its life history, with various recommendations for control.

1815. Tilton, James.—Memoirs of the Philadelphia Society for Promoting Agriculture, vol. 1, p. 192.

Letter from Dr. Tilton to Richard Peters, esq., dated Nov. 16, 1807. Mentions destructiveness of curculio to peaches, and includes extended account of this insect.

1819. Peck, W. D.—Insects which affect oaks and cherries.<Memoirs Agr. Soc. Mass., Agr. Journ., 1819, p. 312.

Description of curculio as *Rhynchænus cerasi*, with figure of beetle.

1819. Muse, Joseph E.—Entomology.<American Farmer, vol. 1, no. 16, pp. 124–125, July 16.

Account of observations and experiments.

1822. Thacher, Dr. James.—The American Orchardist, p. 109.

An extract from Domestic Encyclopædia. Article by Dr. James Tilton, Wilmington, Del. Gives principal points in life history of the plum curculio and mentions several remedies.

---

[1] Titles marked by asterisk (*) have not been verified.

1824. MITCHELL, SAMUEL L.—American Farmer, vol. 6, no. 23, p. 183.

An early systematic account of the curculio.

1826. HARRIS, THADDEUS WM.—New England Farmer, vol. 5, pp. 169–171, December 22.

Remarks on the plum curculio.

1828. "SCRUTATOR."—New England Farmer, vol. 7, pp. 81–82.

Brief description of the curculio, with remarks on its feeding habits, and methods of propagation.

1828. HARRIS, THADDEUS WM.—The curculio, or worm, in fruit.<New England Farmer, vol. 7, pp. 81–82, October 3.

1829. "J. K."—American Farmer, vol. 2, no. 18, p. 140.

An account of the feeding habits of the curculio; also stated that, in addition to destroying the plum, peach, apricot, and nectarine, it is frequently found on the apple.

1829. PRINCE, WM.—A short treatise on horticultúre (1828), p. 22.

Recommends paving around trees as far as branches extend as a means to exterminate the plum curculio.

1829. "J. K."—American Farmer, vol. 9, no. 18, p. 140.

Remarks on the puncturing of fruit by the curculio.

1830. "Anonymous letter to a gentleman of Philadelphia."—American Farmer, vol. 12, No. 34, p. 267.

Description of the plum curculio, written to compete for a premium offered by the Pennsylvania and the Massachusetts Horticultural Societies.

1830. REYNOLDS, S.—American Farmer, vol. 12, no. 23, p. 179.

Recommends wood ashes and lye drenched around the trunks of infested trees as remedy against plum curculio.

1830. HILDRETH, S. P.—New England Farmer, vol. 9, p. 82.

Complaint of the destruction of all stone fruits by the curculio, and encourages the offering of a premium for an effective remedy.

1831. WILSON, WM.—American Farmer, vol. 12, no. 49, p. 389.

Description of the curculio.

1832. MANLY, B.—New Genesee Farmer, vol. 2, pp. 45–53; *id.*, pp. 62–63.

Description of the curculio and reference to remedies.

1838. LEWIS, G. M.—The Cultivator, vol. 5, no. 6, p. 111.

Recommends paving around infested trees as the most effective remedy for the curculio.

1838. MANNING, ROBERT.—Book of fruits, p. 33.

Refers to growing stone fruits by the sea, as the curculio are said to avoid the salt air.

1838. BRIGGS, L. W.—New England Farmer, vol. 16, p. 389.

Recommends use of tin troughs around trees and filled with water and lamp oil to prevent ascent of tree by the curculio.

1840. BURNETT, JOEL.—New England Farmer, vol. 18, p. 304.

Recommends jarring infested trees twice a day as long as the insects are in evidence and collecting dislodged curculios on sheets placed beneath the trees.

1841. HARRIS, THADDEUS WM.—Plum tree grubs.<New England Farmer, vol. 19, p. 405. Figure.

Brief treatment against grub of plum curculio.

Id.—Insects Injurious to Vegetation (1st ed.), pp. 67–69.

Good general account of the plum curculio.

1842. THACHER, JAMES.—The Southern Agriculturist, vol. 2, no. 1, p. 47.

Remedy: Spreading under infested trees lime, wood ashes, fresh seaweed, ground bark from tan pits, coal ashes, etc., to prevent descent into the earth of the curculio.

1843. HARRIS, THADDEUS WM.—Apple worm; curculio plum grub.<New England Farmer, vol. 22, p. 13.

Characteristics of codling moth and curculio.

1843. Burnett, Joel.—Trans. Mass. Hort. Soc., 1843, p. 18.
Résumé of the early accounts of the curculio and methods for its control.

1843. Lovett, Capt.—The Cultivator, vol. 10, no. 9, p. 150.
The plum curculio killed by salt.

1844.* Gaylord, W.—Trans. N. Y. St. Agr. Soc., vol. 3, pp. 314–315.
Prize essay on plum curculio; compiled account of life history, etc.

1844. Kenrick, John A.—The New York Farmer and Mechanic, vol. 1, no. 21, p. 347.
Remedy against plum curculio: Batter of meadow mud well saturated with salt lye spread and spaded to each infested tree.

1844. Jacobs, Benjamin.—The New York Farmer and Mechanic, vol. 2, no. 17, p. 271.
Salt spread over the ground under plum trees as far as spread of limbs prevents curculio arising from ground in early spring, and insures abundant crop of fruit.

1844. Harris, T. W.—New England Farmer, vol. 22, p. 13.
Description of the grub of the plum curculio; distinguished from the apple worm.

1844. Burnett, Joel.—New England Farmer, vol. 22, pp. 49–51.
Description of the curculio with figures of the various stages; life history observations, and methods to be employed for its control. (An essay to compete for an award of $200 for destroying the curculio, offered by the Massachusetts Horticultural Society.)

1847. Landreth, D.—Dictionary of Modern Gardening, p. 176.
Quotes article from "Fruits and fruit trees of North America," by Downing.

1847. Davis, N. S.—Fruits, Insects, etc.<Amer. Journ. Agr. and Sci., vol. 5, pp. 168–169, March.
Injuries produced by the plum curculio discussed.

1848. Hall, Caleb.—The Cultivator, vol. 5, no. 9, p. 278.
Fumigating plum trees with brimstone to protect from ravages of the curculio recommended.

1849. Cole, S. W.—American Fruit Book, p. 204.
An account of the plum curculio, with description and figures of larva, pupa, and adult, and stung plum. Treats of remedies.

1849. Cleveland, H. W. S.—The Horticulturist, vol. 4, no. 3, p. 128.
An account of paving under infested trees to protect crop of fruit from plum curculio.

1849. Spalding, L. A.—The Cultivator, vol. 6, no. 8, p. 247.
An article "Paving vs. Jarring" in treatment against plum curculio.

1849. Sanborn, Eastburn.—New England Farmer, vol. 1, no. 9, p. 137.
An account of breeding experiments to determine habits of the curculio; remedial measures indicated.

1850. Harwell, Robert.—The Horticulturist, vol. 5, no. 6, p. 258.
An account of puncturing of fruit by the curculio.

1850. Gabriel, G.—The Horticulturist, vol. 5, no. 1, p. 22.
Remarks on remedies against plum curculio, namely, gouging eggs out with sharp instrument.

1850. Spalding, L. A.—The Horticulturist, vol. 5, no. 1, p. 30.
An account of paving to destroy the curculio.

1850. Young, L.—The Horticulturist, vol. 5, no. 5, p. 245.
Whitewashing trees and dusting with lime to prevent curculio injury.

1850. Cole, S. W.—The Cultivator, vol. 7, no. 12, p. 395.
Remarks on jarring against the plum curculio.

1850.* Moulson, S.—New England Farmer, vol. 2, no. 24.
Account of the destructiveness of the curculio.

1850. Drake, R. H.—The Cultivator, n. s., vol. 7, p. 47.
Remarks on jarring against the plum curculio.

1850. Sanborn, Eastman.—New England Farmer, vol. 2, no. 12, p. 197.
Account of plum curculio and remarks on remedies.

1850. SIMPSON, H. B.—The Southern Planter, vol. 10, no. 9, p. 265. (From Hovey's Magazine of Horticulture.)

An account of the habits of the curculio with remedial measures for its control.

1850. DRAKE, R. H.—The Cultivator, vol. 7, no. 1, p. 47.

Remarks on jarring against the plum curculio. (Uses a large umbrella to catch falling insects.)

1850. HARRIS, THADDEUS WM.—Injurious insects.<New England Farmer, vol. 2, p. 252.

Habits and ravages of the plum curculio, with remedies.

1850.* H(ARRIS), T. W.—Curious facts in natural history.<Sat. Rambler, vol. 5, no. 47, p. 4, November 23.

Remarks on the plum curculio.

1851. GREEN, HARVEY.—The Genesee Farmer, vol. 12, p. 96.

An account of destroying the curculio by holding burning straw torches around infested trees, into which the beetles fly.

1852. HACKETT, J.—The Horticulturist, vol. 7, no. 1, p. 51.

An account of freeing trees from curculio by throwing common wood ashes all through the branches and over the tree early in the morning when wet with dew.

1852. STOKES, WM.—The Horticulturist, vol. 7, no. 8, p. 350.

Results of spraying trees with whitewash to which has been added flour of sulphur, at the rate of one-half pound to a pailful of whitewash.

1852. BUCHANAN, R.—The Horticulturist, vol. 7, no. 9, p. 438.

Reports good results by the shaking system and details the methods for its operation against the plum curculio.

1852. LUDLOW, THOS. W., JR.—The Horticulturist, vol. 7, no. 9, p. 432.

Ravages of the curculio prevented.

1852. DEAN, JOSHUA.—The Horticulturist, vol. 7, no. 11, p. 528.

"Remedies for the curculio. A new one." (An ounce of sal ammoniac and a pint of soft soap dissolved in 3 gallons of water, thrown on the foliage and fruit with a syringe in the morning, twice or thrice a week.)

1852. "C. E. G."—The Cultivator, vol. 9, n. s., no. 4, pp. 146–147.

Plan of a curculio catcher. Facts and figures showing that the curculio can be certainly, safely, and cheaply resisted.

1852. BIRMINGHAM, H. —The Cultivator, vol. 9, n. s., no. 5, p. 182.

Oil troughs for the curculio.

1852. EVANS, GURDON.—Insects injurious to vegetation. In a general view and agricultural survey of Madison Co., N. Y.<Trans. N. Y. St. Agr. Soc., vol. 11, pp. 745–746, 1851.

1853. BETTS, CHAS.—The Cultivator, vol. 1, no. 5, p. 155.

Throwing air-slaked lime into plum trees to prevent curculio injury.

1853. MAXWELL, S., JR.—The New England Farmer, vol. 5, p. 372.

Discovers eggs of curculio under flap, which he regards as new habit in history of insect. Recommends removal of egg with penknife.

1853. LAKE, J.—New England Farmer, vol. 5, p. 479.

Uses air-slaked lime on trees when fruit sets, applying early in the morning when dew is on. Reports complete success.

1854. PARSONS, JOHN, JR.—American Agriculturist, vol. 13, no. 8, n. s., p. 118.

An account of jarring plan, giving details of the work and indicating number of beetles caught during different years, and amount of sound fruit at harvest time.

1854. LONGWORTH, N.—The Country Gentleman, vol. 3, no. 4, p. 59.

Saves his crop from plum curculio by paving under trees as far as spread of branches.

1854. DOWNING, A. J.—Rural Essays, p. 439.

Remarks on destructiveness of curculio to plum; and states it is less injurious where soil is a stiff fat clay, where curculio finds poor quarters in the soil.

1854. ROBINET, A.—New England Farmer, vol. 6, p. 325.

Quotes Ohio Cultivator; communication to Cincinnati Horticultural Society. Recommends jarring against plum curculio, using two semicircular sheets on hoop frames.

1854. Clement, Asa.—New England Farmer, vol. 6, p. 234.
Describes jarring against plum curculio and recommends use of sheet.

1854. Hadley, Joseph.—New England Farmer, vol. 6, p. 315.
Use of putrid soap suds against plum curculio, followed by dusting with lime.

1854. Chapin, Rubin.—New York Tribune.
Quotes New England Farmer, vol. 6, p. 210. Describes remedy used by J. H. Mather, namely, sulphur, lard, and Scotch snuff, mixed and rubbed freely on body and branches of trees. In a few days curculio all left.

1854. Harris, T. W.—Report on some of the diseases and insects affecting fruit trees and vines.<Proc. Amer. Pom. Soc., p. 215. Sep.: Boston, 11 pp. Rept. Journ. U. S. Agr. Soc. pp. 197–210. Amer. Pom. Soc., 1854.

1855. Wyman, J. P.—New England Farmer, vol. 7, p. 374.
Describes injury of curculio to apple.

1856. Holmes, S. N.—The Country Gentleman, vol. 7, no. 24, p. 383.
Fumigation with tobacco fumes to prevent curculio attack.

1856. Hill, Dr.—The Country Gentleman, vol. 7, no. 26, p. 412.
Experiments to determine migratory habits of curculio.

1856. Pinney, A.—The Genesee Farmer, vol. 17, 2d ser., p. 283.
Remarks on habits of plum curculio, as a peach pest.

1856. Thomas, J. J.—The Country Gentleman, vol. 8, no. 8, p. 142.
Mathew's curculio remedy. Refers to remedies in vogue.

1856. Kirkpatrick, John.—Notes on a few insects of northern Ohio, injurious to the farmer or horticulturist.<10th Ann. Rept. Bd. Agr. Ohio, 1855, pp. 243–244.
Includes remarks on the plum curculio.

1857. Lothrop, D. W.—The Genesee Farmer, vol. 18, 2d ser., p. 286.
Remarks on various remedies against the plum curculio, such as paving, shaking, and syringing the trees with asafœtida, salt water, and strong limewater.

1857. Fowler, Samuel P.—Distribution of insects injurious to vegetation.<4th Ann. Rept. Sec. Mass. Bd. Agr., 1856, pp. 449–450.
Habits and means to be used against the plum curculio.

1858. Darling, Mrs. N.—New England Farmer, vol. 10, p. 73.
Questions raised as to life history of the plum curculio.

1858. White, W. N.—American Agriculturist, vol. 17, no. 8, n. s., p. 245.
Discussion of the shaking method to protect fruit against curculio.

1858. Clay, C. M.—The Country Gentleman, vol. 12, no. 1, p. 14.
Remarks on various curculio remedies.

1858. Affleck, Thomas.—The Country Gentleman, vol. 12, no. 17, p. 272.
Refers to the discovery by an intelligent citizen of a new remedy for the curculio, to be given to the public for some compensation, and makes inquiry about premiums offered by some of the eastern horticultural societies.

1858. Ludlow, Thos. W., Jr.—The Country Gentleman, vol. 12, no. 10, p. 158.
Remarks on habits of the curculio and remedies for protecting fruit against its depredations.

1858. Sanborn, Francis Gregory.—Entomology.<5th Ann. Rept. Sec. Mass. Bd. Agr., 1857, p. 199.
Characters and habits of the plum curculio, and remedies.

1859. Logan, D. B.—The Cultivator, vol. 7, 3d series, no. 3, p. 82.
Remarks on remedy against the plum curculio, namely, whale-oil soap syringed on infested plum trees.

1859. Fitch, Asa.—The Cultivator, vol. 7, 3d series, no. 11, p. 340.
Parasitic enemies of the curculio. Food habits. Describes and figures *Sigalphus curculionis* Fitch, with notes on its habits.

1859. MORRIS, MISS MARGARETA H.—Original observations on insects injurious to our fruits. The Curculio.<Horticulturist, vol. 14, pp. 506–508, pl., and figs. 1–4.

Characters and natural history of the plum curculio.

1860. GOODRICH, CHAUNCEY E.—The Country Gentleman, vol. 15, no. 21 (whole no. 385), p. 334.

The curculio and its repulsion; its natural history and its habits; remedies.

1860. FITCH, ASA.—"Address." On the curculio and blackknot of plum trees. <Trans. N. Y. State Agr. Soc., 1859, vol. 19, pp. 599–612. Separate: Albany, 1860, pp. 15–28.

Description, ravages, and parasite of the plum curculio, and remedies.

1861. WALSH, BENJAMIN DANN.—Insects injurious to vegetation in Illinois.<Trans. Ill. St. Agr. Soc., vol. 4, pp. 345–346, September. Separate: 1861, 43 pp. Repr. (partim), Trans. Ill. Nat. Hist. Soc., vol. 1; Prairie Farmer, December 6, pp. 370–371.

Notes on the plum curculio.

1863. *Id.*—The plum gouger; a new foe of the plum.<Prairie Farmer, vol. 27, n. s. vol. 11, pp. 372–373, figs., June 13.

Compares Anthonomus with Conotrachelus.

1864. *Id.*—The four-humped curculio. A new foe of the apple.<Valley Farmer. Rept. Prairie Farmer, vol. 30, n. s., p. 131, 2 figs., August 27.

Compares with *nenuphar.*

1864. TRIMBLE, I. P.—Injurious insects.<Proc. Amer. Pom. Soc., pp. 93–94.

Habits of the plum curculio.

1865. *Id.*—A treatise on the insect enemies of fruit and fruit trees. New York, 11 pls., pp. 3–102.

An extended account of curculio and codling moth, with numerous colored plates.

1865. SANBORN, FRANCIS GREGORY.—The habits of insects in their relation to man.<12th Ann. Rept. Sec. Mass. Bd. Agr., 1864, p. 158.

Ravages of the plum curculio.

1865. RILEY, C. V.—Flea-beetles and curculio.<Prairie Farmer, vol. 31, n. s. vol. 15, p. 418, fig.

Habits of the plum curculio and remedies; figures pupa.

1865. WALSH, B. D.—On phytophagic varieties and phytophagic species with remarks on the unity of coloration in insects.<Proc. Ent. Soc. Phila., vol. 5, p. 207, Ann. (and Mag.) Nat. Hist., vol. 16, ser. 3, pp. 383–384.

Refers to curculio.

1865. MASTEN, C. R. C.—The Cultivator and Country Gentleman, vol. 27, no. 693, p. 271.

Remarks on habits of the curculio.

1866. WALSH, B. D.—Doctors differ.<Pract. Ent., vol. 1, p. 96, July 30. Criticisms; sheep in orchard do not keep away *nenuphar.* Answer to the above by B. D. W., *ib.*, vol. 2, pp. 31–33, figs. Answer to questions in S. S. Houghton's Insects in the Orchard (*ib.*, pp. 30–31).

Food habits and hibernation of the plum curculio.

1866. RILEY, C. V.—Black-knot once more.<Gardener's Monthly and Horticulture, vol. 8, pp. 331–332, November.

Larvæ present in swellings of (*Sphæria*) *Plowrightia morbosa* Sacc.

1866. HOUGHTON, J. S.—Insects in the orchard.<Pract. Ent., Dec., vol. 2, pp. 30–31.

Notes on the plum curculio.

1866. BRACKETT, G. F.—Practical Entomology No. 10.<Maine Farmer, July 19.

Description of the plum curculio and means to be taken against it.

1867. TRIMBLE, ISAAC P.—An insect talk.<Amer. Pom. Soc., pp. 119–120.

Habits of the plum curculio and means to be taken against it.

1867. RILEY, C. V.—The curculio.<Prairie Farmer, vol. 35, n. s. vol. 19, p. 381.

Successful use of machines for destroying the plum curculio; hibernates as adult.

Id.—vol. 36, n. s. vol. 20, p. 148.

Answer to inquiry regarding plum curculio; means to be taken against same.

Id.—vol. 39, n. s. vol. 23, p. 122.

Answer to inquiry regarding plum curculio; habits and means to be taken against same.

1867. HILL, FRANKLIN C.—The little Turk and its crescent.<Pract. Ent., August–September, vol. 2, pp. 114–115.

Oviposition of the plum curculio.

1867. WALSH, B. D.—Means against curculio: Œstridæ.<Pract. Ent., vol. 2, p. 97.

Answer to inquiry regarding the plum curculio; ineffective remedies against same.

Id.—pp. 75–81.

Characters of the Rhynchophora, with injuries, life history, food habits, number of generations, and remedies.

Id.—p. 71. Extr. from Genesee Farmer, 1853, p. 125. Fighting the curculio.

Ridicules recommendation of remedies other than jarring against plum curculio.

Id.—Prairie Farmer, vol. 36, n. s. vol. 20, p. 359.

Ravages and means against.

Id.—Pract. Ent., vol. 2, pp. 114–115.

Comments on correspondence; oviposition of plum curculio.

Id.—First annual report on the noxious insects of the State of Illinois.<Trans. Ill. St. Hort. Soc., 1867, n. s., vol. 1, Appendix, pp. 64–72. Separate: Chicago, 1868, figs.

History, generations, enemies of the plum curculio, and remedies.

1868. HARRIS, THADDEUS WM.—Insects injurious to vegetation (3d edition), pp. 75–82.

1868. RILEY, C. V.—Report of committee on entomology.<Trans. Ill. St. Hort. Soc., 1867, n. s., vol. 1, pp. 112–114.

Habits and food plants of the plum curculio, and injuries inflicted by same.

1868. WALSH, B. D.—The bug-hunter in Egypt. A journal of an entomological tour into south Illinois by the senior editor.<Amer. Ent., vol. 1, pp. 11–14, figs.

Id.—pp. 33–36.

Predaceous enemies of the curculio.

Id.—The six worst insect enemies of the fruit growers in northern Illinois. <Trans. Ill. Hort. Soc., 1867–68, p. 94.

1868. WALSH, B. D., and RILEY, C. V.—Hogs vs. bugs.<Amer. Ent., vol. 1, pp. 3–6.

Swine as enemies of the plum curculio; favorable quotations.

Id.—Entomological quackery.<Amer. Ent., vol. 1, p. 56. Rept. of "The Curculio," Iowa Homestead, July 22, 1868.

Comments on the plum curculio; means against same.

1868. WALSH, B. D., and RILEY, C. V.—Curculio and barklice.<Amer. Ent., vol. 1, p. 80.

Reply to inquiry regarding plum curculio; hibernation of same.

Id.—p. 241. Comparative scarcity of the curculio again.

Observations during summer of 1869.

1869. RILEY, C. V.—1st Ann. Rept. on noxious insects, etc., of the State of Missouri. <4th Ann. Rept. St. Bd. Agr., 1868, pp. 50–52, 6 figs.

Excellent account of plum curculio and résumé.

1869.* RILEY, C. V.—Prairie Farmer, July 10, vol. 40, n. s. vol. 24, p. 218, fig.

Apple leaf crumpler mistaken for curculio. Correspondence: Improper use of the word *Curculio;* means against. Figs.

*Id.**—

Reply: Recommends jarring against plum curculio.

1869. WALSH, B. D., and RILEY, C. V.—Plums for the million.<Amer. Ent., vol. 1, pp. 92–93.

Remedies. Varieties of plums exempt from attack by plum curculio.

Id.—p. 161. Curculio remedies.

Comments on an essay on the plum; coal oil not effective against plum curculio.

Id.—p. 183. Another new curculio humbug.

Extract from an agricultural paper, with criticisms.

Id.—p. 202. The curculio scarcer than last year.

Excerpt from correspondence; comparative scarcity of the curculio in 1869.

Id.—pp. 217–218. Is the curculio scarcer than it was last year?

Observations to prove it so.

Id.—p. 226. A new curculio humbug.

Reply: Usefulness of a patented lamp.

1869. "G. G."—Hogs vs. Curculio.<Rural New Yorker, August 28. Reprint: Amer. Ent., vol. 2, p. 56, November.

Usefulness of hogs against plum curculio.

1869. FRANCIS, LUCIUS O.—Curculio remedies.<Amer. Ent., vol. 1, p. 161.

1869. BROWN, A. M.—Curculio notes.<Amer. Ent., vol. 1, pp. 239–241.

Habits and natural history of the plum curculio.

1869. BAYLER, JOHN C.—The plum curculio.<Amer. Ent., vol. 2, p. 53.

1870. TRIMBLE, ISAAC P.—The plum curculio will deposit in fruit which overhangs water.<Amer. Ent., vol. 2, pp. 119–120.

Tests and arguments to prove that trees planted over water are not protected from attacks of the plum curculio.

1870. PULLEN, B.—Hindrances to successful fruit growing.<Amer. Ent. and Bot., vol. 2, p. 170.

Remedies against plum curculio.

1870. LE BARON, W.—Prairie Farmer, vol. 41, p. 338, October 29.

Habits of the plum curculio.

Id.—p. 258.

Character and habits of the plum curculio.

1870. HARTWELL, J. B.—Notes from Wilkinsonville, Mass.<Amer. Ent. and Bot., vol. 2, p. 336.

Injuries inflicted by plum curculio.

1870. RILEY, C. V.—The plum curculio (*Conotrachelus nenuphar* Herbst.).<Amer. Ent., vol. 2, pp. 130–137, fig. 92.

Summary of knowledge concerning the plum curculio, with discussion of disputed points.

Id.—p. 165. Is any knowledge useless?

Reprint of an article in Manufacturer & Builder, November, 1869. Cases in which knowledge of minute scientific facts will be of great value.

Id.—pp. 225–227. Notice: Cultivator and Country Gentleman, vol. 35, pp. 360–361. Great discovery. Curculio extermination possible!

Reprint of articles on destruction of curculio; criticisms; remedies, etc.

Id.—The new curculio remedy, p. 243.

Id.—p. 276. The plum curculio breeds in apple.

Reply to correspondent regarding the plum curculio.

1870. RILEY, C. V.—The Ransom curculio remedy.<Amer. Ent., vol. 2, pp. 268–271.
Efficiency of the "Ransom chip-trap against the plum curculio"; criticism of articles on this subject.

Id.—pp. 338. Paris green for the curculio.
Paris green ineffective against the plum curculio.

1871. SAUNDERS, W.—Hints to fruit growers. Paper No. 1.<Can. Ent., vol. 3, p. 12.
Remedies against the plum curculio.

1871.* Reed, E. B.—Insects affecting the plum.<Rept. Fruit Growers' Assn. Ontario, 1870, pp. 120–126, 7 figs.
Characters and habits of the plum curculio, and remedies against same.

1871. LE BARON, W.—The plum curculio and the plum gouger, striped grapevine caterpillar. Notes to correspondents.<Prairie Farmer, vol. 42, p. 171, June 3.
Habits of the plum curculio.

1871. LEBARON, W.—Insects injurious to fruits.<Trans. North. Ill. Hort. Soc., pp. 85–89.
Brief notes on the plum curculio.

1871. GLOVER, TOWNEND.—Report of the entomologist and curator of the museum. <Rept. U. S. Comm. Agr. for 1870, pp. 68–70.
Brief note on the plum curculio.

1871. RILEY, C. V.—Third Annual Report on the noxious, beneficial, and other insects of the State of Missouri.<6th Ann. Rept. St. Bd. Agr. f. 1870, pp. 11–29, 9 figs. Separate: Jefferson City, Mo., April, 1871.
Details in life history of the plum curculio and means of control.

1871. SAUNDERS, W.—Hints to fruit growers. Paper No. 2.<Can. Ent., vol. 3, p. 26, 1 fig.
Remedies against the plum curculio.

1872.* LEBARON, W.—Southern Illinois curculio experiments.<Prairie Farmer, June 15.
Notes on hibernation of the plum curculio and remedies against same.

1872. MEEHAN, T.—Insects on cherry trees.<Gardener's Monthly, vol. 14, n. s. vol. 5, p. 154.
Remedies against the plum curculio.

1872. GLOVER, TOWNEND.—Report of the entomologist and curator of the Museum. <Rept. U. S. Comm. Agr. f. 1871, p. 77.
Remedies against the plum curculio.

1872. WIER, D. B.—Insects most noxious to fruit growers.<Trans. Wisc. St. Hort. Soc. f. 1872, pp. 165–167, 1 fig.
Includes and deals with curculio.

1872. RILEY, C. V.—Einige unserer schadlicherer Insekten, St. Louis, pp. 18–26, 5 figs.
Descriptions and figures of the plum curculio; habits, injuries, parasites, enemies, and remedies.

Id.—Economic entomology.<Trans. Kans. St. Bd. Agr., 1872, pp. 320–323, 2 figs.
A chapter on curculio.

1873. *Id.**—Curculio on pears.<Ill. Journ. Agr.
Habits and history of the plum curculio, and remedies against same.

1874.* TRACEY, WM. W., and Geo. Parmelee.—Injurious insects. Traverse City, Mich.; 12 pp.

1874. RILEY, C. V.—The Cultivator and Country Gentleman, vol. 39, p. 310. Copied from the Tribune.)
Remarks on habits of the plum curculio and life-history notes.

1874.* *Id.*—The plum curculio; natural history; and how to catch him. N. Y. Semi-Weekly Tribune, May, 1874.

Natural history of the plum curculio and remedies; figures several stages and machines in use.

1875. Thomas, J. J.—Diseases and enemies of the plum.<4th Rept. Secy. St. Pom. Soc. Mich., 1874, pp. 35–36.

Remedies against the plum curculio.

1875. Lyon, T. T.—Plums and plum culture in Michigan.<4th Ann. Rept. Secy. St. Pom. Soc. Mich., 1874, pp. 237–238.

Habits of the plum curculio and injuries.

1875. Cook, A. J.—Insects injurious to the farm, garden, and orchard.<13th Ann. Rept. Sec. St. Bd. Agr. Mich., 1874, pp. 133–136, 2 figs., Separate, 1875, 48 pp., 2 figs.

1875. Bessey, C. E.—Report on insects injurious to plants and animals of the farm. <Rept. Iowa St. Agr. Soc., 1874, pp. 236–238, 1 fig. Separate: Des Moines, 1875.

1876. Fernald, Charles Henry.—Destructive insects, their habits, and means of preventing their depredations.<3rd Ann. Rept. Sec. Maine St. Pom. Soc., 1875, pp. 23–24.

Notes on life history of the plum curculio.

1876.* Riley, C. V.—Plums and cotton.<N. Y. Weekly Tribune, May 17.

Reply to inquiries regarding the plum curculio. Bands of cotton around trees.

1877. Packard, Alpheus Spring.—Report on the Rocky Mountain locust and other insects now injuring or likely to injure field and garden crops in the Western States and Territories.<Rept. U. S. Geol. Surv., 1875, p. 795.

Notes on the plum curculio.

1877. Gott, B.—Report on some of our fruit insect enemies.<Ann. Rept. Ent. Soc. Ont., 1877, p. 46, 1 fig.

Observations on the plum curculio.

1878. Saunders, W.—Annual address of the president of the Entomological Society of Ontario.<Can. Ent., vol. 10, p. 187, October; *ib.*, p. 7.

Notes on the plum curculio.

1878. Perkins, G. H.—On some of the injurious insects of Vermont.<Bd. Agr., 1878, p. 268.

1879. Gott, B.—Notes of the year.<Ann. Rept. Ent. Soc. Ont., 1878, p. 56.

Observations on the plum curculio.

1879.* Riley, C. V.—Preventing rot in plums.<N. Y. Tribune, April 9.

Propping and jarring recommended against the plum curculio.

1880. Gott, B.—The plum curculio (*Conotrachelus nenuphar*).<Ann. Rept. Ent. Soc. Ont., 1879, pp. 84–88, figs. 55–57.

Habits of the plum curculio, injuries, parasites, and remedies.

1881. Lintner, Joseph Albert.—Insects on plum trees.<Cultivator and Country Gentleman, vol. 46, p. 376, June 9.

The plum curculio recorded attacking cherry.

1883. Riley, C. V.—Recent advances in horticultural entomology.<Rural New Yorker, vol. 42, October 20. Reprint, p. 693.

Discussion of remedies.

1883. Weed, Clarence Moores.—Injurious insects new to Michigan.<15th Ann. Rept. Sec. St. Hort. Soc., 1882, p. 185.

Scarcity of curculio noted.

1883. Devereaux, W. L.—Coal tar for the plum weevil.<Can. Ent., vol. 15, p. 236, December.

Inefficacy of same.

1883. CLAYPOLE, E. W.—Entomological notes for the summer of 1881.<Rept. Ent. Soc. Ont., 1882, p. 26.

Injuries and remedies.

1884. WEED, CLARENCE MOORES.—The plum curculio again.<Prairie Farmer, October 4.

Notes on jarring.

1884. RILEY, C. V.—Curculio, plum.<Supp. Encycl. Brit., 9th ed., vol. 2, p. 494.

Natural history and remedies.

1884. SAUNDERS, W.—Annual address of the president of the Entomological Colonial Society of Ontario.<Can. Ent., vol. 16, p. 208, November.

1885. *Id.*—Short notes.<15th Ann. Rept. Ent. Soc. Ont., 1885, pp. 17, 18.

1885. WEED, CLARENCE MOORES.—The plum curculio.<Prairie Farmer, vol. 57, p. 345, May 30.

Life history of the plum curculio; recommends jarring as a remedy.

1885. FLETCHER, JAMES.—Report of the Entomologist.<Rept. Min. Agr. [Canada], p. 25, 1 fig.

1885. FORBES, S. A.—Experiments on the codling moth and curculios (*Carpocapsa pomonella* Linn.; *Anthonomus quadrigibbus* Say; *Conotrachelus nenuphar* Herbst).<Trans. Ill. St. Hort. Soc., 1885, n. s., vol. 19, pp. 103–119. Prairie Farmer, December 19, 1885.

Details of experiments with arsenicals.

1886. WEBSTER, F. M.—Insects of the year.<Trans. Ind. Hort. Soc., 1885, p. 60.

Characters of the plum curculio and injuries; remedies against same.

1886. SAUNDERS, W.—Annual address of the president of the entomological society of Ontario.<Can. Ent., vol. 18, p. 184, October. 17th Ann. Rept. Ent. Soc. Ont., 1887, p. 6.

Brief note on the plum curculio.

1887. STICKNEY, J. P.—Insect pests.<Trans. Wisc. St. Hort. Soc., vol. 17, p. 235.

Injuries produced by the plum curculio and remedies.

1887. LINTNER, JOSEPH ALBERT.—The curculio on the apple.<Cultivator and Country Gentleman, vol. 52, p. 565, July 21.

Probable injuries to apples by plum curculio; remedies against same.

1887. DORAN, E. W.—Report on the economic entomology of Tennessee.<Bien. Rept. Comm. Agr., etc., Tenn., pp. 221–224, 1 fig.

History of the plum curculio and remedies.

1887. COOK, A. J.—Notes on noxious insects.<26th Ann. Rept. Sec. St. Bd. Agr. Mich., 1886–1887, p. 451.

Notes on the plum curculio.

1887. COOK, A. J.—Experiments of Department of Zoology and Botany.<26th Ann. Rept. Sec. St. Bd. Agr. Mich., 1886–1887, pp. 40–45.

Remedies against the plum curculio.

1887. WIER, D. B.—Bul. 14, o. s., Div. Ent., U. S. Dept. Agr., pp. 49–52.

Extended discussion to show that native plums are practically curculio proof.

1887. WEED, CLARENCE M.—Notes on Ohio Insects.<Ohio Farmer, Aug. 4, p. 66.

Brief notes on the plum curculio.

Id.—Recent developments in insect warfare.<Ohio Farmer, pp. 214, 230, 246, figs., October 6, 12, 20.

Notes on the plum curculio.

Id.—Some experiments in preventing the injuries of the plum curculio.< Proc. 9th Ann. Meet. Soc. Prom. Agr. Sci., pp. 90–95, 1 diagram.

1888. WEED, CLARENCE M.—Report of the Entomologist.<7th Ann. Rept. Ohio Agr. Exp. Sta., pp. 146–150, 1 fig.

Notes on the plum curculio.

1888. Cook, A. J.—Bul. 39, Mich. Agr. Coll. Exp. Sta., p. 8, September.
Results of spraying with arsenicals for plum curculio,

1888. Treat, Mary.—Curculio and injury to cherries.<Prairie Farmer, p. 538, August 18.

1888. Harvey, F. L.—Report of the botanist and entomologist.<Ann. Rept. Maine Agr. Exp. Sta., pp. 178–181, 1 fig.
Treats of plum curculio.

1888. Fernald, C. H.—Injurious insects.<Trans. Mass. Hort. Soc., p. 112.
Notes on the plum curculio.

1888. McMillan, Conway.—Twenty-two common insects of Nebraska. Bul. Nebr. Sta., vol. 1, no. 2, pp. 45–50, fig. 1.
Separate.

1888. Comstock, John Henry.—Serious injury to apples by plum curculio.<Ins. Life, vol. 1, p. 193.

1888. Brackett, G. C.—Rebuttal of Wier's statement regarding the plum curculio. <Ins. Life, vol. 1, p. 193.

1888. Weed, Clarence M.—Seasonable insect notes.<Prairie Farmer, vol. 60, p. 273, April 28.
London purple as a remedy against the plum curculio.

1888. Ashmead, Wm. Harris.—Entomological section.<Bul. 2, Fla. Agr. Exp. Sta., pp. 14–16.
Notes on the plum curculio.

1888. Lintner, J. A.—Proceedings New York Farmers, 1886–1887, 1 fig., pp. 53–54.
Remedies against the plum curculio.

1888. Bethune, Charles J. S.—Remedies for noxious insects.<18th Ann. Rept. Ent. Soc. Ont., 1 fig., pp. 53, 54.
Characters of the plum curculio and habits.

1888. Comstock, John Henry.—On the destruction of the plum curculio by poisons. <Bul. 3, Cornell Univ. Agr. Exp. Sta., pp. 40–43.
The reason why poisons are effective against this insect as shown by experiment, and by quotations from Weed and Forbes.

1888. Wier, B. D.—The curculio and the plum.<Farmer's Review, p. 644, October 10.

1889. Weed, Clarence M.—Recent developments in insect warfare.<Ann. Rept. Ohio St. Hort. Soc. f. 1888–1889, pp. 24, 25.
Remedies against the plum curculio.

1889. Marten, J.—Arsenical poisons for the plum and peach curculio.<Prairie Farmer, p. 516, 1 fig, August 10.

1889. Weed, Clarence M.—Practical remedies for some Ohio insects; II. Insecticides and their application.<Bul. 8, Ohio Agr. Exp. Sta., pp. 4, 5; 1 fig.

Id.—Remedies for the plum curculio.<Bul. Ohio Agr. Exp. Sta., 2d ser., vol. 2, no. 6, pp. 133–143.

Id.—Experiments with remedies for the plum curculio.<Ent. Amer., pp. 204–207, October and November.

Id.—Further experiments in preventing the injuries of the plum curculio. <Proc. 10th Ann. Meet. Soc. Prom. Agr. Sci., pp. 101–107.
One diagram.

1889. Webster, F. M.—Experiments in rearing the plum curculio from plums and other fruits.<Rept. Comm. Agr., 1888, pp. 78–79.

Id.—Entomological experiments.<Bul. 25, Ind. Agr. Exp. Sta., pp. 5–9, 1 fig.
Experiments against the plum curculio.

1889. WEBSTER, F. M.—Entomology.<Ann. Rept. Ind. St. Bd. Agr., pp. 555–557.
Notes on the plum curculio.

1889. NEAL, J. C.—Entomologist's report.<Bul. 4, Fla. Agr. Exp. Sta., p. 14.
Short notes on the plum curculio.

1889. RILEY, C. V.—The plum curculio, arsenical sprays, Wier's wild plum immunity theory.<Proc. 22d sess. Amer. Pom. Soc., pp. 13–36.

1889. SMITH, J. B.—Report of the entomologist.<10th Ann. Rept. N. J. Agr. Exp. Sta., pp. 296–298.
Brief account of the plum curculio.

1889. COOK, A. J.—Remedies for curculio.<Rural New Yorker, p. 677, October.

1889. GILLETTE, C. P.—Important injurious insects.<Bul. 5, Iowa Agr. Exp. Sta. p. 181.
Notes on the plum curculio.

1889. BUDD, J. L.—Curculio-proof plums.<Orchard and Garden, p. 137, July.

1889. BECKWITH, M. H.—Injurious insects.<Bul. 4, Del. Agr. Exp. Sta., pp. 10–12, 1 fig.; 2d Ann. Rept. Del. Agr. Exp. Sta., pp. 120–122, 1 fig.
Brief account of the plum curculio.

1889. WIER, B. D.—The plum curculio.<Fruit Grower's Journal, November 1.

1889. BRUNER, LAWRENCE.—Report of the entomologist.<Ann. Rept. Nebr. St. Bd. Agr., 1888, pp. 124–127, 1 fig.
Treats of plum curculio.

1889. RILEY, C. V., and HOWARD, L. O.—The plum curculio.<Rept. Ent. in Rept. Comm. Agr. for 1888, pp. 57–79.
Detailed account of the plum curculio, with remedies.

1890. WEED, C. M.—I. Plum curculio experiment.<Bul. Ohio Agr. Exp. Sta., 2d ser., vol. 3, no. 8, pp. 225–228.

Id.—A third season's experiments with remedies for the plum curculio. <Proc. 11th Ann. Meet. Soc. Prom. Agr. Sci., 1890, pp. 44–46.

Id.—A season's work among the enemies of the horticulturist.<Proc. Ohio St. Hort. Soc., p. 12.
Notes on the plum curculio.

1890. SMITH, J. B.—Notes on the plum curculio.<Garden and Forest, 1890, p. 560.

1890. WEBSTER, F. M.—Experiments with the plum curculio.<Ins. Life, vol. 2, pp. 305–310, April.

Id.—Entomological notes.<Bul. 33, Ind. Agr. Exp. Sta., pp. 36–41, 1 fig.

1890. RILEY, C. V., and HOWARD, L. O.—The puncturing of apples by the plum curculio.<Ins. Life, vol. 2, pp. 383–384, 1 fig., May and June.
Short note on injury to apples by the plum curculio.

1890. REYNOLDS, H.—The plum curculio.<Massachusetts Ploughman, August 9.

1890. BECKWITH, M. H.—Our injurious insects.<Trans. Penin. Hort. Soc., pp. 87, 88.

1890. GREEN, S. B.—London purple for the curculio on native plums.<Bul. 10, Minn. Agr. Exp. Sta., pp. 71, 72.
Remedies against the plum curculio.

1890. WEBSTER, F. M.—Entomological notes.<Bul. 33, Ind. Agr. Exp. Sta., pp. 36–39.
Experiments against plum curculio.

1890. HOPKINS, A. D.—Report of the entomologist.<3d Ann. Rept. W. Va. Agr. Exp. Sta., pp. 151, 152.
Remedies against the plum curculio.

1890. Chittenden, F. H.—Notes on the habits of some species of Rhynchophora. <Ent. Amer., p. 170, September.

Biological notes on the plum curculio.

1890. Lelong, B. M.—Injurious insects.<Rept. Cal. St. Bd. Hort., 1889, pp. 223–228, 2 figs.

Treats of plum curculio.

1890. Cook, A. J.—The plum curculio.<Bul. 66, Mich. Agr. Exp. Sta., p. 8, 1 fig.

Various remedial measures against the plum curculio.

1890. Cook, A. J.—Latest methods with curculio.<Proc. Mich. Hort. Soc., 1889, pp. 37–39, 1 fig.

1890. Gillette, C. P.—The plum curculio and the plum gouger.<Bul. 9, Iowa Agr. Exp. Sta., pp. 371–378.

Life history notes and parasites of the plum curculio, with remedies. Relative injury to varieties of plums.

1890. Murtfeldt, M. E.—Entomological notes from Missouri for the season of 1899. <Bul. 22, Div. Ent., U. S. Dept. Agr., p. 74.

1890. Osborn, Herbert.—Entomology.<Orange Judd Farmer, p. 372, June 14.

Experiments relative to plum curculio.

1890. Osborn, Herbert.—Entomology.<Orange Judd Farmer, p. 277, May 3.

Notes on the plum curculio.

1891. Weed, H. E.—Injurious insects.<Miss. Agr. Exp. Sta., Bul. 14, pp. 22–26, 1 fig.

General account of the plum curculio.

1891. Weed, C. M.—A review of some plum curculio literature.<Amer. Nat., pp. 63–72, January.

Id.—Insect talks—17.<Natl. Stockman and Farmer, p. 587, figs., October 8.

Id.—Insect injuriously affecting fruits, shade trees, and flowers.<Ann. Rept. Columbus Hort. Soc., 1890, pp. 60–62, 1 fig.

Brief account of the plum curculio.

1891. Smith, J. B.—Notes on the plum curculio.<Ins. Life, vol. 3, pp. 219, 220, January.

Id.—Report of the Entomologist.<12th Ann. Rept. N. J. Agr. Exp. Sta., pp. 420–423, 1 fig.

Reprint of Buls. 82 and 85 and Spec. Bul. N, with brief additions.

1891. Fernald, C. H.—Division Entomology.<Bul. 12, Mass. Agr. Exp. Sta., p. 16, 1 fig.

Brief note on the plum curculio.

1891. Forbes, S. A.—Transactions Department of Agriculture of Illinois.<17th Rept. Ill. St. Ent. Separate: Springfield, Ill., pp. 21–25.

Experiments with arsenites against the plum curculio.

1891. Hopkins, A. D.—(1) Farm and garden insects. (2) Notes of the season. <Bul. 14, W. Va. Agr. Exp. Sta., pp. 71, 72.

Brief notes on the plum curculio.

1891. Gillette, C. P.—Notes on the plum curculio and plum gouger.<Ins. Life, vol. 3, pp. 227–229.

Egg-laying record of the plum curculio and remedies.

1891. Lintner, J. A.—7th Rept. on injurious and other insects of the State of New York.<44th Rept. N. Y. Mus. Nat. Hist., pp. 288–296, 4 figs.

Review of the year, with notes on plum curculio.

1891. McCarthy, G.—Some injurious insects.<Bul. 78, N. Car. Agr. Exp. Sta., p. 261, 1 fig.

Brief compiled notes on the plum curculio.

1891. MURTFELDT, M. E.—Entomological notes for the season of 1890.<Bul. 23, Div. Ent., U. S. Dept. Agr., p. 47.
Short notes on the plum curculio.

1891. OSBORN, H.—Entomology.<Orange Judd Farmer, p. 356, June 6.

1891. OSBORN, H.—Entomology.<Orange Judd Farmer, p. 36, July 18.

1891. FLETCHER, J.—Recommendations for the prevention of damage by some common insects of the farm, the orchard, and the garden.<Bul. 11, Can. Exp. Farms, p. 23.
Remedies against the plum curculio.

1891. WEED, C. M.—Miscellaneous experiments in the control of injurious insects. <Ohio. Agr. Exp. Sta. Bul., vol. 4, no. 2, p. 42.
Deals with spraying as remedy against plum curculio.

1891. MURTFELDT, M. E.—Entomological notes for the season. Reports of observations and experiments in the practical work of the Division of Entomology. <Bul. 26, Div. Ent., U. S. Dept. Agr., p. 37.
Brief note on the plum curculio.

1892. SMITH, J. B.—Spraying for insect and fungous pests of the orchard and vineyard.<Bul. 86, N. J. Agr. Exp. Sta., p. 5.
Treatment for plum curculio.

1892. KINNEY, L. F.—Fungicides and insecticides.<Bul. 15, R. I. Agr. Exp. Sta., p. 25.
Treatment for plum curculio.

1892. COOK, A. J.—Entomological reports.<Rept. Mich. Agr. Exp. Sta., f. 1891–92, pp. 123–127.
Use of arsenicals against plum curculio.

1892. SMITH, J. B.—Spraying for insect pests of the orchard.<Bul. 86, N. J. Agr. Exp. Sta., p. 5.
Remedies against plum curculio.

1892. RILEY, C. V.—Remedies for the plum curculio.<American Farmer, p. 24, March 1.
Traps and spraying against plum curculio.

1892. MARTEN, J.—Description of the 25 horticultural insects referred to in this article on page 121.<Trans. Ill. St. Hort. Soc., pp. 219–222, 1 fig.
Describes insects earlier mentioned by Forbes, including the plum curculio.

1892. STINSON, J. T.—Some insects and fungous diseases and their remedies. <Bul. 21, Ark. Agr. Exp. Sta., pp. 59, 60.
Spraying against the plum curculio.

1892. FLETCHER, JAMES.—Injurious insects.<Farmer's Advocate, London, Ontario, p. 199, 1 fig.
Economic notes on plum curculio.

1892. GARMAN, H.—Some common pests of the farm and garden.<Bul. 40, pp. 34, 35, Kent. Agr. Exp. Sta., and 5th Ann. Rept., pp. 74, 75.
Treats of plum curculio.

1893. WEED, C. M.—A second season's work among the enemies of the horticulturist.<Proc. Ohio St. Hort. Soc., pp. 3–11, fig.

1893. ALWOOD, W. B.—Injurious insects and diseases of plants, with remedial measures for the same.<Bul. 24, Va. Agr. Exp. Sta., p. 8.

1893. MURTFELDT, M. E.—Report on Insects of Missouri for 1892. Report of observations and experiments in the practical work of the Division of Entomology. <Bul. 30, Div. Ent., U. S. Dept. Agr., p. 56.
Scarcity of parasites of the plum curculio.

1893. Weed, C. M.—The treatment of neglected apple orchards.<Rept. N. H. Agr. Exp. Sta., f. 1893, p. 175.
Brief account of the plum curculio.

1893. Goff, E. S.—The plum curculio in Door County, Wisconsin.<Ins. Life, vol. 6, pp. 36–38.
Notes on plum curculio.

1894. Webster, F. M.—Plum curculio insect in dewberry.<Ohio Farmer, p. 117, February 8.

1894. Sturgis, W. C.—Some injurious insects.<18th Ann. Rept. Conn. Agr. Exp. Sta., pp. 141–142.
Brief notes on plum curculio.

1894. Stinson, J. T.—Insects injurious to fruits and vegetables, and remedies for destroying them.<Bul. 33, Ark. Agr. Exp. Sta., pp. 74–77, 1 fig.

1894. Price, R. H.—Injurious fungi and insects.<Bul. 32, Tex. Agr. Exp. Sta., pp. 493, 494, 1 fig.
Remedies against plum curculio.

1894. Lugger, Otto.—A few enemies of the plum.<Ann. Rept. Minn. St. Hort. Soc., pp. 417–418, 1 fig.
Notes on plum curculio.

1894. Bruner, Lawrence.—Insect enemies of the apple tree and its fruit.<Ann. Rept. Nebr. St. Hort. Soc., p. 161.
Plum curculio listed.

1894. Jack, A. G.—The plum curculio as an apple pest.<Garden and Forest, pp. 44–45.

Id.—Notes on some injurious insects.<Trans. Mass. Hort. Soc., p. 140.
Notes on plum curculio.

1894. Hatch, A. L.—Enemies of orchard fruits.<Trans. Ill. St. Hort. Soc., pp. 323–325.
Treats of plum curculio.

1895. Smith, J. B.—The plum curculio on apple.<Garden and Forest, p. 104.

1895. Slingerland, M. V.—The plum curculio on apples.<Rural New Yorker, p. 457, July 6.

1895. Fletcher, James.—Report of the entomologist and botanist.<Rept. Exp. Farms, Canada, 1894, p. 156, 1 fig.
Economic notes on plum curculio.

1895. Marion, J. H.—The plum curculio.<Colman's Rural World, p. 203, June 27.
Experience with jarring for plum curculio.

1895. Murtfeldt, M. E.—Habits of the plum curculio.<Colman's Rural World, p. 35, January 31.

1895. Fletcher, J.—Injurious insects.<Bul. 23, Exp. Farms, Canada, p. 21, 1 fig.
Remedies against plum curculio.

1895. Schwarz, E. A.—Some notes on Melsheimer's Catalogue of the Coleoptera of Pennsylvania.<Proc. Ent. Soc. Wash., vol. 3, p. 137.
Comments on Melsheimer's error in believing curculio oviposited in peach twigs.

1895. Riley, C. V.—(Comments on above paper by Mr. Schwarz—) Proc. Ent. Soc. Wash., vol. 3, p. 138.
States that Melsheimer's statement might to a certain extent be correct. Records finding oviposition marks on pear twigs.

1895. McCarthy, G.—The peach tree and its parasites.<Bul. 120, N. C. Agr. Exp. Sta., p. 293, 1 fig., November.
Mentions plum curculio.

1896. SLINGERLAND, M. V.—Spotted plums.<Rural New Yorker, p. 672, October 10.

Work of plum curculio.

1896. SLINGERLAND, M. V.—Report as chairman of committee on entomology. <Proc. West. N. Y. Hort. Soc., 1896, pp. 18–19.

Notes on plum curculio.

1896. GOFF, E. S.—Miscellaneous horticultural work.<Wisc. Agr. Exp. Sta. Rept. f. 1895, p. 303.

Notes on plum curculio.

1896. PRICE, R. H.—The peach.<Bul. 39, Tex. Agr. Exp. Sta., pp. 844–845, 1 fig.

Brief notice, injuries to peach, remedial measures with reference to plum curculio.

1896. LUGGER, OTTO.—Insects injurious in 1896.<Bul. 48, Minn. Agr. Exp. Sta., 1896, pp. 69–71, 1 fig., December.

1897. WEBSTER, F. M., and MALLY, C. W.—Insects of the year in Ohio.<Bul. 9, n. s., Div. Ent., U. S. Dept. Agr., p. 43.

Brief notes on plum curculio.

1897. SLINGERLAND, M. V.—Life history of the plum curculio.<Rural New Yorker, p. 354, 1 fig., May 29.

Id.—Plum curculio and its eggs.<*Ib.*, p. 420, June 26.

1897. JOHNSON, W. G.—Destructive insects and methods of controlling them. <American Gardening, no. 1, p. 22, January 2.

Id.—March 13, p. 174, 1 fig.

1897. BOGUE, E. E.—Some injurious orchard insects.<Bul. 26, Okla. Agr. Exp. Sta., p. 18, 1 fig.

Brief note on the plum curculio.

1897. BUTZ, GEORGE C.—The peach industry in Pennsylvania. Curculio (*Conotrachelus nenuphar*).<Bul. 37, Pa. Agr. Exp. Sta., p. 27.

Brief notes on the plum curculio; recommends jarring.

1897. FLETCHER, JAMES.—Report of the entomologist and botanist.<Rept. Exp. Farms, Canada, 1896, p. 255.

Brief note on the plum curculio.

1897. JOHNSON, WILLIS G.—Notes from Maryland on the principal injurious insects of the year.<Bul. 9, n. s., Div. Ent., U. S. Dept. Agr., p. 82.

Records great injury to peaches; also attack of apples, pears, and plums.

1897. PANTON, J. H.—Instructions in spraying.<Bul. 105, Ont. Agr. College and Exp. Farms, p. 10.

Remedies against plum curculio.

1897?. KINNEY, L. F.—The plum rot and its effect on plum culture in Rhode Island. <Rept. R. I. Agr. Exp. Sta., p. 191, 1896.

1897?. EARLE, F. S.—Japanese plums.<Bul. 85, Ala. Agr. Exp. Sta., pp. 423–448.

Remedies against plum curculio.

1897?. GOFF, E. S.—Miscellaneous Horticultural Work.<Wisc. Agr. Exp. Sta., Rept., 1896, pp. 234–235.

Remedies against plum curculio.

1897. LELONG, B. M.—Insect pests and tree diseases liable to be introduced into the State and especially to be guarded against.<5th Bien. Rept. Cal. St. Bd. Hort., 1895–1896, p. 25.

1898. SMITH, J. B.—Report of the entomological department of the New Jersey Agricultural College Experiment Station for 1897.<Ann. Rept. N. J. Agr. Exp. Sta., 1897, pp. 404–405.

Brief note on plum curculio.

1898. GILLETTE, C. P.—Colorado's worst insect pests and their remedies.<Bul. 47, Colo. Agr. Exp. Sta., p. 22.
Brief account of the plum curculio.

1898. JOHNSON, W. G.—Report on the San Jose scale in Maryland, and remedies for its suppression and control.<Bul. 57, Md. Agr. Exp. Sta., p. 6.
Brief notes on plum curculio.

1898. SLINGERLAND, M. V.—How the curculio mounts the plum trees.<Rural New Yorker, p. 656, September 24.

1898. FAVILLE, E. E., and PARROTT, P. J.—Some insects injurious to the orchard. <Bul. 77, Kans. Agr. Exp. Sta., pp. 41–43, fig. 1.
Notes on the plum curculio.

1898. FERNALD, H. T.—Insects to be treated now by fruit growers. The apple worm and plum curculio.<Farmer's Cir. 2, Pa. Dept. Agr., May.
Brief account of the plum curculio.

1899. SLINGERLAND, M. V.—How insects spend the winter.<Rural New Yorker, p. 55, January 28; p. 116, February 18.

1899. WEBSTER, F. M.—Inquiries answered.<Ohio Farmer, p. 382, November 16.
Transformation of the plum curculio.

1899. TILLINGHAST, J. A., and ADAMS, G. E.—Suggestions as to spraying.<Bul. 52, R. I. Agr. Exp. Sta., pp. 35–36.
Brief account of the plum curculio.

1899. STARNES, HUGH N.—Some peach notes.<Bul. 42, Ga. Agr. Exp. Sta., pp. 227–228, 1 fig.
Brief account of the plum curculio.

1899. HARVEY, F. L., and MUNSON, W. M.—Apple insects of Maine.<Bul. 56, Maine Agr. Exp. Sta., pp. 134–136.
General account of the plum curculio, with description of stages.

1899. LUGGER, OTTO.—Beetles injurious to fruit-producing plants.<Bul. 66, Minn. Agr. Exp. Sta., pp. 285–290, 6 figs.
Popular account of the plum curculio.

1899. JOHNSON, W. G.—Miscellaneous entomological notes.<Bul. 20, n. s., Div Ent., U. S. Dept. Agr., p. 64.
Mention of the plum curculio.

1899. BEACH, S. A., LOWE, V. H., and STEWART, F. C.—Common diseases and insects injurious to fruits.<Bul. 170, N. Y. St. Agr. Exp. Sta., pp. 433–434.
Brief account of the plum curculio.

1899. FLETCHER, JAMES.—Report of the entomologist and botanist.<Rept. Exp. Farms Can., 1898, pp. 202–203.
Destruction of apples and plums by the plum curculio.

1899. BRUNER, LAWRENCE.—Insect enemies of the apple and its fruit.<Ann. Rept. Nebr. St. Hort. Soc., 1898, p. 208, 1 fig.
Note on the plum curculio.

1899. FERNALD, H. T.—Some insects attacking fruit and fruit trees.<Bul. 47, Pa. Dept. Agr., pp. 18–19.
Brief account of life history, injuries, and treatment of the plum curculio.

1899. DOANE, R. W.—Insects and diseases affecting the prune.<Bul. 38, Wash. Agr. Exp. Sta., pp. 43–44.
Brief description of the plum curculio and remedies against same.

1900. CLOSE, C. P.—Plant diseases and insect pests.<Bul. 65, Utah Agr. Exp. Sta., pp. 87–88.
Remedies against plum curculio.

1900. COOLEY, R. A.—Injurious fruit insects.<Bul. 23, Mont. Agr. Exp. Sta., pp. 78, 79, 1 fig.
Brief account of the plum curculio; injuries, life history, and remedies.

1900. JOHNSON, W. G.—Notes on insects of economic importance for 1900.<Bul. 26, n. s., Div. Ent., U. S. Dept. Agr., p. 83.
Brief note on the plum curculio.

1900. Sanderson, E. D.—Notes from Delaware.<Bul. 26, n. s., Div. Ent., U. S. Dept. Agr., p. 67.
Brief note on the plum curculio.

1900. Smith, J. B.—The plum curculio.<Ent. Cir. 17, N. J. St. Bd. Agr., pp. 2.
Remedies against the plum curculio.

1900. Weed, C. M.—Insect record for 1899.<Bul. 72, N. H. Agr. Exp. Sta., pp. 68–69.
Notes on the plum curculio.

1901. Bruner, L., and Hunter, W. D.—Insect enemies of the stone fruits.<Ann. Rept. Nebr. St. Hort. Soc., 1900, pp. 111–113, 1 fig.
Life history of the plum curculio and remedies against same.

1901. Felt, E. P.—Plum curculio.<Country Gentleman, p. 604, July 25.
Injury to leaves of plum by plum curculio.

1901. Felt, E. P.—16th Rept. on the injurious and other insects of the State of New York.<Bul. N. Y. St. Mus., vol. 7, no. 36, p. 989, 1900.
Brief account of the plum curculio.

1901. Fletcher, James.—Report of the Entomologist and Botanist.<Ann. Rept. Exp. Farms, Can., 1900, p. 239.
Injury to apples by the plum curculio.
Brief note on the plum curculio.

1901. Green, E. C.—Insect enemies of tree and fruit and how to control them. <Trans. Ill. Hort. Soc., 1900, pp. 114–125, p. 122.
Remedies against the plum curculio.

1901. Quaintance, A. L.—Insect notes.<13th Ann. Rept. Ga. Agr. Exp. Sta., 1900, p. 365.
Brief note on the plum curculio.

1901. Slingerland, M. V.—Do curculios crawl or fly?<Rural New Yorker, p. 104, February 16.

1901. Slingerland, M. V.—Fighting the plum curculio.<Rural New Yorker, p. 288, April 20.
Coal tar does not give sufficient results.

1901. Smith, W. B.—Insect enemies to fruit and their remedies.<Proc. Columbus Hort. Soc., p. 61.
Remedies against the plum curculio.

1901. Snyder, A. H.—Insects injurious to fruit.<Proc. Columbus Hort. Soc., p. 56.
Brief note on the plum curculio.

1901. Fletcher, J.—31st Ann. Rept. Ent. Soc. Ontario.<Rept. Ont. Ent. Soc., 1900, p. 71.
Brief note on the plum curculio.

1901. Sherman, F., Jr.—Injurious insects.<Bul. 6, N. C. St. Bd. Agr., vol. 22, pp. 27–28, 1 fig.

1902. Banks, N.—Principal insects liable to be distributed on nursery stock.<Bul. 34, n. s., Div. Ent., U. S. Dept. Agr., pp. 45–46.
Biological notes on the plum curculio.

1902. Cranefield, F.—Plum insects and diseases.<Wisc. Agr., p. 10, January 9.
Recommends jarring against the plum curculio.

1902. Fiske, W. F.—Notes on certain injurious insects in Georgia.<Proc. Ga. St. Hort. Soc., 1902, p. 77.
Discusses remedies for use against the plum curculio.

1902. Gillette, C. P.—Insects and insecticides.<Bul. 71, Colo. Agr. Exp. Sta., p. 14.
Brief description of the plum curculio.

1902. Goff, E. S.—Coal tar for plum curculio.<Wisc. Agr., p. 11, May 15.
Advises against coal tar as remedy for plum curculio.

1902. GOSSARD, H. A.—Report of committee on entomology.<Trans. Fla. Hort. Soc., p. 101.

Brief note on the plum curculio.

1902. HOWARD, L. O.—Notes from correspondence.<Bul. 38, n. s., Div. Ent., U. S. Dept. Agr., p. 109.

Treats of parasites of the plum curculio.

1902. JOHNSON, W. G.—Insect warfare in peach orchards.<American Agriculturist, p. 588, April 26.

Jarring for plum curculio.

1902. MUNSON, W. M.—Habits of the plum curculio.<Rural New Yorker, p. 302, April 26.

1902. MURTFELDT, M. E.—Drought, heat, and insect life.<Bul. 31, n. s., Div. Ent., U. S. Dept. Agr., pp. 97, 98.

Note on effect of drought on the plum curculio.

1902. MURTFELDT, M. E.—Recent experiments with destructive insects.<Rept. Mo. State Hort. Soc., p. 254.

Plum curculio not much reduced in numbers by unusual climatic conditions.

1902. SCOTT, W. M., and FISKE, W. F.—Jarring for the curculio on a large scale in Georgia, with a list of the insects caught.<Bul. 31, n. s., Div. Ent., U. S. Dept. Agr., pp. 24–27, 2 pls.

Account of jarring for plum curculio on a large scale.

1902. SLINGERLAND, M. V.—What the plum curculio does.<Rural New Yorker, p. 400, June 7.

Habits of the plum curculio.

1902. SMITH, J. B.—The entomologist's experiment orchard.<Bul. 155, N. J. Agr. Exp. Sta., pp. 54, 56.

Life history of the plum curculio and remedies against same.

1902. STEDMAN, J. M.—Some orchard pests.<34th Ann. Rept. Mo. St. Bd. Agr., p. 220.

Brief note on the plum curculio.

1902. FERNALD, H. T.—Some common pests of the farmer.<Bul. 99, Pa. Dept. Agr., pp. 23, 24.

Life history of the plum curculio and remedies against same.

1902. SMITH, J. B.—Report of the Entomologist.<N. J. Agr. Exp. Sta. Rept., 1901, p. 484.

Brief account of the plum curculio.

1902. QUAINTANCE, A. L., and SMITH, R. I.—Egg-laying record of the plum curculio. <Bul. 37, n. s., Div. Ent., U. S. Dept. Agr., pp. 105–107.

Table showing egg deposition of 9 female curculios during their lives.

1902. EDWARDS, C. H.—Second biennial report of the Montana State Board of Horticulture.<Mont. St. Bd. Hort., Rept., 1901–2, p. 80.

Brief note on the plum curculio.

1903. TITUS, E. S. G.—Insects other than the codling moth injurious to the fruit of the apple.<Trans. Ill. St. Hort. Soc. for 1902, pp. 138–162.

Life history of the plum curculio and habits of same.

1903. WASHBURN, F. L.—Injurious insects of 1903.<Bul. 84, Minn. Agr. Exp. Sta., p. 88, 1 fig. Also 8th Rept. St. Ent. Minn., p. 88, 1 fig.

Notes on the plum curculio.

1903. CHITTENDEN, F. H.—The principal injurious insects in 1902.<Ybk. Dept. Agr., 1902, p. 731.

Mention of plum curculio.

1903. FELT, E. P.—19th Report of the State Entomologist on injurious and other insects of the State of New York.<Bul. 76, N. Y. St. Mus., p. 137.

Brief notes on the plum curculio.

1903. SURFACE, H. A.—Monthly Bulletin, Division Zoology, vol. 1, no. 2, Pa. Dept. Agr., June, p. 11.

Brief note on the plum curculio.

1903. SHERMAN, F., JR.—Injurious insects. Spraying for insects and diseases. <Bul. 24, N. C. St. Bd. Agr., 1903, no. 6, pp. 28–29, 1 fig.

Short descriptive, biological, and economic notes on the plum curculio.

1903. OSBORN, H.—The insect problem.<Columbus Hort. Soc., vol. 18, no. 2, pp. 41, 42.

Statistics showing extent of damage by the plum curculio.

1903. SANDERSON, E. D.—Report of the entomologist.<Del. St. Rept. 1902, pp. 109–151.

Arsenicals found to be effective in control of plum curculio on cherry but not on apple.

1903. HORSFALL, F.—Orchard enemies.<Bul. 9, Mo. Fruit Station, pp. 27, 28.

Notes on habits, life history, and means of combating the plum curculio.

1903. SHERMAN, F., JR.—Insect enemies of apple, pear, and quince, with methods of treatment.<Bul. 183, N. C. Agr. Exp. Sta., p. 59, 1 fig.

Brief economic and biological notes on the plum curculio.

1903. SHERMAN, F., JR.—Insect and fungus enemies of the peach, plum, cherry, fig, and persimmon.<Bul. 186, N. C. Agr. Exp. Sta., pp. 7–8.

Brief notes on the plum curculio.

1903. HORSFALL, F.—Orchard enemies.<Bul. 9, Mo. Fruit Station, p. 27.

Remedies against the plum curculio.

1904. LOCHHEAD, W.—Insects of the season.<34th Ann. Rept. Ent. Soc. Ont., 1903, p. 33.

Note on occurrence of the plum curculio.

1904. PETTIT, R. H.—Insects injurious to fruits in Michigan.<Spec. Bul. 24, Mich. Agr. Exp. Sta., pp. 65, 66.

Brief account of life history of the plum curculio and remedies against same.

1904. SLINGERLAND, M. V.—Some serious insect depredations in New York in 1903. <Bul. 46, Div. Ent., U. S. Dept. Agr., p. 72.

Remedies against the plum curculio.

1904. SLINGERLAND, M. V.—Save the quinces and plums.<American Agriculturist, p. 551, May 14.

Remedies against the plum curculio.

1904. WEED, C. M.—The insect record for 1903.<Bul. 115, N. H. Agr. Exp. Sta., p. 174; Ann. Rept., 1904, p. 259.

Brief notes on the plum curculio.

1904. FORBES, S. A.—Spraying apples against the plum curculio.<Bul. 52, Bur. Ent., U. S. Dept. Agr., p. 49. Papers read before Ass. Econ. Ent., Dec. 30, 1904. Published as Bulletin 108, Ill. Agr. Exp. Sta. (May, 1906).

1904. FARRAND, T. A.—Report of the South Haven Substation for 1903.<Spec. Bul. 27, Mich., pp. 3–4.

Dust *v.* liquid sprays against the plum curculio.

1904. CHITTENDEN, F. H.—The principal injurious insects of 1903.<Ybk. Dept. Agr. f. 1903, p. 565.

Remedies against the plum curculio.

1904. COOLEY, R. A.—1st Annual Report of the State Entomologist of Montana. <Bul. 51, Mont. Agr. Exp. Sta., p. 256.

Remedies against the plum curculio.

1904. FLETCHER, J.—Insects of the year in Canada.<Bul. 46, Bur. Ent., U. S. Dept. Agr., p. 82.

Mention of the plum curculio.

1904. SURFACE, H. A.—Monthly Bulletin, Division of Zoology, vol. 2, no. 2, Pa. Dept. Agr., p. 63, June.

Remedies against the plum curculio.

1904. WASHBURN, F. L.—9th Annual Report of the State Entomologist of Minn., pp. 109–115, 3 figs.

Plum curculio as enemy to apples; discusses injuries, habits, and remedies.

1904. SANDERSON, E. DWIGHT.—The plum curculio.<Cir. 6, Ent. Dept. Texas Agr. Exp. Sta., pp. 1–3, 3 figs.

Brief summarized account of the plum curculio.

1904. FULTON, J. A.—Peach culture, p. 133.

Discusses plum curculio, giving numerous proposed remedies.

1904. COOLEY, R. A.—2d Annual Report of the State Entomologist.<Bul. 55, Mont. Agr. Exp. Sta., pp. 171–172.

Brief account of the plum curculio.

1904. STEDMAN, J. M.—The sting in the apple. The work of the plum curculio in the apple.<Bul. 64, Mo. Stat., pp. 24, 10 figs.

Discusses the life history and habits of the plum curculio in apple orchards; remedies.

1904. CHITTENDEN, F. H.—The cherry fruit fly.<Bul. 44, Div. Ent., U. S. Dept. Agr., p. 72, figs. 18.

Introduces new figures, showing larva, pupa, and adult of plum curculio.

1904. WASHBURN, F. L.—Injurious insects of 1904.<Rept. St. Ent. Minn., 1904, pp. 109–115, 3 figs.

Discussion of injury to apples by plum curculio.

1905. CRANDALL, C. S.—The curculio and the apple.<Bul. 98, Ill. Agr. Exp. Sta.

An extended account of the plum and apple curculios, giving results of thorough life-history studies and experiments with arsenical sprays during 1903 and 1904.

1905. BRITTON, W. E.—Fourth Report of the State Entomologist.<Conn. Storrs Stat. Rept., 1904, pt. 3, pp. 219–221, 1 fig.

Injury to apples by curculio.

1905. BURGESS, A. F.—Report of the chief inspector of nurseries and orchards. <Ohio Dept. Agr., Div. Nurs. and Orch. Insp., Rept., 1905, pp. 10–11.

1905. QUAINTANCE, A. L.—The principal insect enemies of the peach.<Ybk. U. S. Dept. Agr., pp. 325–330, 1905.

General account of curculio, with recommendations for use of arsenicals; jarring and cultivations.

1906. JOHNSON, F., and GIRAULT, A. A.—The plum curculio.<Cir. 73, Bur. Ent., U. S. Dept. Agr., pp. 10, 5 figs.

Life history and habits of plum curculio; remedies.

1906. SLINGERLAND, M. V.—Cooperative spraying experiments.<Bul. 235, Cornell Agr. Exp. Sta., pp. 160–165.

Report on results of arsenate of lead against plum curculio by New York orchardists.

1906. QUINN, G.—Seasonable notes on some orchard pests.<Journ. Dept. Agr. So. Austr., vol. 10, no. 1, pp. 9–14.

Remedies against plum curculio.

1907. ADAMS, C. F.—Some insects of orchard and other fruits.<Bul. 92, Ark. Agr. Exp. Sta., pp. 11–12, 1 fig.

Brief biological and economic notes on plum curculio.

1907. SMITH, J. B.—Report of the Entomologist.<N. J. Sta. Rept. f. 1906, p. 520.

1907. HOUGHTON, C. O.—Report of the Entomologist.<Del. Coll. Agr. Exp. Sta. Repts., 1905–1906, pp. 83–85.

Remedies. Little benefit was noted from the use of sticky bands in capturing plum curculio.

1908. MORRIS, O. M., and NICHOLSON, J. F.—Orchard spraying.<Bul. 76, Okla. Agr. Exp. Sta., pp. 23–24, 1 fig.

Brief account of the plum curculio.

1908. PATCH, EDITH M.—Insect notes for 1908.<Bul. 162, Maine Agr. Exp. Sta., p. 363.

Brief account of the plum curculio.

1908. WASHBURN, F. L.—The apple leafhopper and other injurious insects of 1907 and 1908.<Bul. 112, Minn. Agr. Exp. Sta., pp. 227–234, 4 figs.

Results of spraying plum trees with arsenate of lead against plum curculio: life history notes.

1908. SMITH, J. B.—Insecticide materials and their application, with suggestions for practice.<Bul. 213, N. J. Agr. Exp. Sta., pp. 45–46.

Remedies against plum curculio.

1908. TAYLOR, E. P.—Report of the department of entomology.<Mo. State Fruit Exp. Sta., Rept., 1907–8, pp. 13–14.

Results of experimental spraying against plum curculio.

1908. WORSHAM, E. L.—Report of the past year's work of the State board of entomology.<Bul. 27, Ga. St. Bd. Ent., pp. 76–78.

Notes on experimental spraying with arsenical poison against plum curculio.

1909. WORSHAM, E. L.—Proceedings of the Twenty-first Annual Meeting of the American Association of Economic Entomologists.<Journ. Econ. Ent., vol. 2 (1909), no. 3, pp. 207–208.

Results of spraying with arsenate of lead against the plum curculio.

1909. HOUGHTON, C. O.—Report on insects.<Trans. Pa. Hort. Soc. Del., vol. 22, pp. 42–43.

1909. TAYLOR, E. P.—Spraying apples for curculio and codling moth.<Bul. 21, Mo. State Fruit Exp. Sta., pp. 11–18, 3 figs.

Life history and habits of the plum curculio, and spraying experiments against same.

1910. SCOTT, W. M., and QUAINTANCE, A. L.—Control of the brown rot and plum curculio on peaches.<Cir. 120, Bur. Ent., U. S. Dept. Agr.

1910. QUAINTANCE, A. L., et al.—The one-spray method in the control of the codling moth and the plum curculio.<Bul. 80, Pt. VIII, Bur. Ent., U. S. Dept. Agr.

Gives results in experiments in control of plum curculio on apple.

1911. SCOTT, W. M., and QUAINTANCE, A. L.—Spraying peaches for the control of the brown rot, scab, and curculio.<Farm. Bul. 440, U. S. Dept. Agr.

Results of experimental and demonstration spraying of peaches for their several troubles in 1910.

1911. BLAKE, M. A., and FARLEY, A. J.—Spraying experiments with peaches.<Bul. 236, N. J. Agr. Exp. Sta.

Results of experiments in spraying peaches for brown rot, scab, and curculio.

INDEX.

Page.

Acorn weevil. (See *Balaninus victoriensis.*)
Ambrosia, host plant of stalk-borer, *Triaspis curculionis* reared therefrom...... 143
Ampeloglypter sesostris, host of *Myiophasia ænea*.............................. 149
Anaphes conotracheli. (See *Anaphoidea conotracheli.*)
Anaphoidea conotracheli, parasite of plum curculio.......................... 140–142
Anisocyrta sp., parasite of plum curculio.. 148
Anthonomus grandis, host of *Myiophasia ænea*................................... 149
Triaspis curculionis............................... 143
quadrigibbus. (*See* Apple curculio.)
scutellaris mistaken for plum curculio........................... 28
Antimony, black sulphid, against plum curculio.................................... 206
Ants, enemies of plum curculio... 152
Apple, crab, food plant of plum curculio.. 33
curculio mistaken for plum curculio.. 28
results of sprays therefor.. 192
spraying with arsenicals... 201
food plant of apple curculio (*Anthonomus quadrigibbus*)........... 28, 192, 201
bud moth (*Tmetocera ocellana*)........................... 201
cankerworms.. 201
codling moth (*Carpocapsa pomonella*)..................... 201
Enarmonia prunivora... 201
plum curculio.. 33
tent caterpillar.. 201
order of preference in oviposition by plum curculio.................... 33
scab, spraying with Bordeaux mixture or lime-sulphur................. 201
spraying against plum curculio at Anderson, Mo........................ 193–194
St. Joseph, Mo..................... 198–199
Siloam Springs, Ark................ 196
conclusions........................... 200–201
early experiments.................... 189–193
experiments by Bureau of Entomology 193–200
in Virginia.............................. 197–198
western New York and northwestern Pennsylvania..................... 195
scheme for orchards against plum curculio.................................. 201
susceptibility of different varieties to plum curculio..................... 36
worm, lesser. (See *Enarmonia prunivora.*)
Apricot, food plant of plum curculio.. 33
order of preference in oviposition by plum curculio.................. 33
Aramigus fulleri mistaken for plum curculio....................................... 29
Arsenate of iron, paste, against plum curculio..................................... 188
on peaches.......................... 206
and self-boiled lime-sulphur against plum curculio.... 188
powder, against plum curculio on peaches................... 206

Page.
Arsenate of lead against apple curculio 192
bud moth on apple 201
plum curculio 185–189
on apple 191–193, 196, 198, 199, 200
peaches 203–215
and Bordeaux mixture against apple insects 201
plum curculio on apple 191–192, 194–199
lime-sulphur against apple insects 201
water, injurious effects on peach 207
self-boiled lime-sulphur against plum curculio. 188, 205, 211–216
directions for using 213
injury to peach variable 207
powdered, against plum curculio 187
Arsenicals (*see also* Poisons, etc.).
against plum curculio on apple, early experiments 189–193
experiments by Bureau of Entomology 193–200
cherries and plums 215–218
peaches 202–215
plums and cherries 215–218
spraying against plum curculio 178–185
Arsenic sulphid against plum curculio on peaches 204, 206
and self-boiled lime-sulphur against plum curculio on peaches. 206
red, against plum curculio 186–188
on peaches 206
injurious effects on peach 207
powder, and self-boiled lime-sulphur against plum curculio 188
yellow, paste, against plum curculio 188
and self-boiled lime-sulphur against plum curculio 188
tersulphid against plum curculio 186–188
on peaches 206
injurious effects on peach 207
powder, and self-boiled lime-sulphur against plum curculio 188
white, against plum curculio 181
on apple 191
and Bordeaux mixture against plum curculio on apple 191
Arsenite of lime against apple curculio 192
plum curculio on apple 191–192, 200
and Bordeaux mixture against plum curculio on apple 191–192
Arsenoid, green, against plum curculio on peaches 203
injurious effects on peach 207
Aspidoglossa subangularis, enemy of plum curculio 152–153
Balaninus sp., host of *Triaspis curculionis* 143
uniformis, host of *Myiophasia ænea* 149
victoriensis mistaken for plum curculio 29
Barium carbonate against plum curculio 206
sulphid against plum curculio 206
Birds, enemies of plum curculio 154
Black knot, breeding place of plum curculio 33
of cherry and plum, use for egg laying and food purposes by plum curculio 37

Page.
Bluestone, lime, and Paris green dust, homemade, against plum curculio on apple 194, 200
Boll weevil, cotton. (See *Anthonomus grandis.*)
Bordeaux mixture against plum curculio on apple 196, 198
and arsenate of lead against orchard insects 201
plum curculio on apple 191–192, 194–199
arsenite of lime against plum curculio on apple 191–192
Paris green against apple curculio 192
plum curculio 183
on apple 191–192, 194
white arsenic against plum curculio on apple 191
Bracon dorsata, parasite of plum curculio 148
mellitor. (See *Microbracon mellitor.*)
Bud moth on apple, spraying with arsenicals 201
Calyptus tibiator, parasite of *Myiophasia ænea* 149
Cankerworms, spraying with arsenicals 201
Carbonate of lead against plum curculio 206
Chalcodermus æneus, host of *Myiophasia ænea* 149
sp., host of *Myiophasia ænea* 149
Chauliognathus pennsylvanicus, enemy of plum curculio 154
Cherries, susceptibility of different varieties to attack by plum curculio 36–37
Cherry, food plant of plum curculio 33
order of preference in oviposition by plum curculio 33
weevil, common name for plum curculio 14
Cholomyia inæquipes, parasite of *Conotrachelus affinis* 150
elegans 150
juglandis 150
plum curculio 150–151
synonyms 150
Chrysopa larvæ, enemies of plum curculio 152
Commercial dust against plum curculio on apple 194–200
Conotrachelus affinis, host of *Cholomyia inæquipes* 150
Triaspis curculionis 143
elegans, host of *Cholomyia inæquipes* 150
Myiophasia ænea 149
Triaspis curculionis 143
gibbosus=*Conotrachelus nenuphar* 14
juglandis, host of *Cholomyia inæquipes* 150
Metadexia basalis 150
Triaspis curculionis 143
nenuphar. (*See* Plum curculio.)
variegatus=*Conotrachelus nenuphar* 14
Copper sulpho-cyanid against plum curculio 206
Cratægus, food plant of plum curculio 33
Cryptorhynchus argula=*Conotrachelus nenuphar* 14, 16
Cultivation for destruction of plum curculio pupæ 176–178
Curculio, common name for plum curculio 14
nenuphar=*Conotrachelus nenuphar* 14
original description 13–14
origin of name 14–15
persicæ=*Conotrachelus nenuphar* 14
plum. (*See* Plum curculio.)

Page.
Currant, place of oviposition of plum curculio 33
Diospyros virginiana. (*See* Persimmon, wild.)
Dorymyrmex pyramicus, enemy of plum curculio 152
Eggplant, host plant of *Trichobaris trinotata* 143
Enarmonia prunivora, larvæ with those of plum curculio in black knot 142
spraying with arsenicals 201
Epicærus imbricatus mistaken for plum curculio 29
Epiurus sp. (*See* Pimpla.)
Eurytoma, parasite of plum curculio 148
Evarthrus obsoletus, enemy of plum curculio 154
orbatus, enemy of plum curculio 154
Ferrous arsenate against plum curculio 187
powder, against plum curculio 188
and self-boiled lime-sulphur against plum curculio 188
Fowls, enemies of plum curculio 154
Fruit curculio, common name for plum curculio 14
Fruits, smooth-skinned, preferred for oviposition by plum curculio 33
Gooseberry, place of oviposition by plum curculio 33
Grape, larvæ of plum curculio fail to mature therein 38
place of oviposition by plum curculio 33
Grosbeak, rose-breasted. (See *Zamelodia ludoviciana.*)
Harpalus faunus, enemy of plum curculio 153–154
pennsylvanicus, enemy of plum curculio 153–154
Heliophila unipuncta, possible host of *Myiophasia ænea* 149
Hickory, host tree of *Conotrachelus elegans* 149
Huckleberry, larvæ of plum curculio fail to mature therein 38
place of oviposition of plum curculio 33
Hylocichla fuscescens, enemy of plum curculio 154
g. pallasi, enemy of plum curculio 154
Icterus galbula, enemy of plum curculio 154
spurius, enemy of plum curculio 154
Jarring against plum curculio 168–176
present status 172–176
"Kerkelo," common name for plum curculio 14
Lacewing fly larvæ, enemies of plum curculio 152
Lanivireo flavifrons, enemy of plum curculio 154
Lead arsenate. (*See* Arsenate of lead.)
oxid against plum curculio 206
Lime against plum curculio on apple 189–190
bluestone, and Paris green dust, homemade, against plum curculio on apple 194, 200
sulphur and arsenate of lead against apple insects 201
self-boiled, and arsenate of lead against plum curculio on peaches 205, 211–216
arsenicals against plum curculio 187–188, 205–215
directions for preparation 212
Little Joker, common name for plum curculio 14
Turk, common name for plum curculio 14
London purple against plum curculio 182–185
on apple 189–190
peaches 202, 203
Metadexia basalis, parasite of *Conotrachelus juglandis* 150
probably = *Cholomyia inæquipes* 150

Page.
Microbracon mellitor, parasite of plum curculio........ 148
Musca longipes=*Cholomyia inæquipes*........ 150
Myiophasia ænea, host of *Calyptus tibiator*........ 149
parasite of *Ampeloglypter sesostris*........ 149
Anthonomus grandis........ 149
Balaninus uniformis........ 149
Chalcodermus æneus........ 149
sp........ 149
Conotrachelus elegans........ 149
plum curculio........ 149–150
Sphenophorus parvulus........ 149
possible parasite of *Heliophila unipuncta*........ 149
Nectarine, food plant of plum curculio........ 33
order of preference in oviposition by plum curculio........ 33
Nenuphar, common name for plum curculio........ 14
Oriole, Baltimore. (See *Icterus galbula.*)
orchard. (See *Icterus spurius.*)
Paris green against apple curculio........ 192
plum curculio........ 178–185
on apple........ 189–192, 200
peaches........ 202–207
and Bordeaux mixture against apple curculio........ 192
plum curculio........ 183
on apple........ 191–192, 194
injurious effects on peach........ 207
lime, and bluestone dust, homemade, against plum curculio on apple........ 194, 200
Peach curculio, common name for plum curculio........ 14
food plant of plum curculio........ 33
order of preference in oviposition by plum curculio........ 33
shoots, ovipositing place of plum curculio........ 38
weevil, common name for plum curculio........ 14
worm, common name for plum curculio........ 14
Peaches, spraying with arsenicals against plum curculio........ 202–215
susceptibility of different varieties to plum curculio........ 36
Pear, bark, ovipositing place of plum curculio, according to Fitch........ 38
food plant of plum curculio........ 33
larvæ of plum curculio usually unable to mature therein........ 38–39
order of preference in oviposition by plum curculio........ 33
Pears, susceptibility of different varieties to plum curculio........ 36
Pegomya fusciceps, association with plum curculio in fruit........ 151
Persimmon, larvæ of plum curculio fail to mature therein........ 38
wild, place of oviposition by plum curculio........ 33
Pimpla (*Epiurus*) sp., parasite of plum curculio........ 148
Plowrightia morbosa. (*See* Black knot.)
Plum curculio, adult (*see also* Plum curculio, beetles).
activity in egg laying and feeding by day and night... 107–110
choice of food........ 96–97
description........ 33
egg and feeding punctures, position on fruit and variation in form........ 103–106
laying operation........ 99–102

Page.
Plum curculio, adult, extent of feeding of respective sexes.......... 98–99
period of emergence.......... 92–95
proportion of sexes.......... 95–96
relative number of feeding and egg punctures.......... 106–107
appearance of beetles in spring, relation of temperature thereto. 118–120
time.......... 112–118
beetles (*see also* Plum curculio, adult).
appearance in spring, relation of temperature thereto.. 118–120
time.......... 112–118
from emergence to hibernation.......... 127–129
occurrence in orchards.......... 120–125
bibliography.......... 219–241
classification.......... 13–14
description.......... 30–33
distribution.......... 19–27
according to life zones.......... 25
egg and feeding punctures, position on fruit and variation in
form.......... 103–106
relative number.......... 106–107
description.......... 30
laying and feeding activity by day and by night.......... 107–110
operation.......... 99–102
length of stage.......... 48–54
number deposited.......... 39–48
enemies, natural.......... 139–154
feeding and egg laying activity by day and by night.......... 107–110
punctures, position on fruit and variation in
form.......... 103–106
relative number.......... 106–107
food plants.......... 33–39
fruit punctured or infested, percentage.......... 134–139
generations, number annually.......... 125–127
habits.......... 39–112
hibernation.......... 129–132
mortality during period.......... 132–134
history.......... 15–19
insects likely to be mistaken therefor.......... 28–29
introductions reported.......... 26
larva, description.......... 30–32
habits of those just hatched and course taken in fruit.... 54–55
instars.......... 55–56
larvæ, death in fruit.......... 56–59
fruits in which they fail to mature.......... 38
manner of leaving fruit and entering soil.......... 64–65
normal emergence from fruit during season.......... 60–64
undersized, desertion of fruit.......... 59–60
life history.......... 39–112
limit of occurrence, northern.......... 24–25
southern.......... 25
western.......... 21–24
losses due thereto.......... 27–28
mortality during hibernation.......... 132–134
names, common.......... 14–15

Page.
Plum curculio, natural enemies ... 139–154
occurrence of beetles in orchards ... 120–125
parasitic enemies ... 140–152
percentage of fruit punctured or infested ... 134–139
predaceous insect enemies ... 152–154
pupa, description ... 32
length of stage and time spent in soil, before and after pupation ... 83–87
time spent in soil ... 73–83
pupæ, cultivation for destruction ... 176–178
pupal cell, depth ... 87–88
remedial measures ... 155–218
historical ... 155–167
remedies, cultivation for destruction of pupæ ... 176–178
jarring ... 168–176
feeding experiments with poisons ... 185–189
premiums therefor ... 167–168
Ransom chip process ... 168
spraying with arsenicals ... 178–185
seasonal history ... 112–134
spraying scheme for apple orchards ... 201
of apple at Anderson, Mo ... 193–194
St. Joseph, Mo ... 198–199
Siloam Springs, Ark ... 196
conclusions ... 200–201
early experiments ... 189–193
experiments by Bureau of Entomology ... 193–200
in Virginia ... 197–198
western New York and northwestern Pennsylvania ... 195
peaches with arsenicals ... 202–215
plums and cherries ... 215–218
synonymy ... 13–14
time for transformation from egg to adult ... 110–112
of appearance of beetles in spring ... 112–120
spent in fruit, egg and larval stages combined ... 65–73
transformations in ground, effect of soil conditions thereon ... 88–92
food plant of plum curculio ... 33
gouger. (See *Anthonomus scutellaris.*)
moth, so-called. (See *Enarmonia prunivora.*)
order of preference in oviposition by plum curculio ... 33
weevil, common name for plum curculio ... 14
Plums, cultivated, variation in susceptibility to plum curculio ... 34–36
Poisons (*see also* Arsenicals, etc.).
against plum curculio, feeding experiments ... 185, 189
Porizon conotracheli. (See *Thersilochus conotracheli.*)
Potato-stalk weevil. (See *Trichobaris trinotata.*)
Premiums for remedies for plum curculio ... 167–168
Prunus americana, food plant of plum curculio ... 36
angustifolia, food plant of plum curculio ... 36
domestica, food plant of plum curculio ... 36
hortulana, food plant of plum curculio ... 36
simonii, apparently not injured by plum curculio ... 35

Page.
Prunus triflora, food plant of plum curculio 35
umbellata, food plant of plum curculio 36
Quince, food plant of plum curculio 33
order of preference in oviposition by plum curculio 33
Ransom chip process against plum curculio 168
Rhynchænus argula=Conotrachelus nenuphar 14
cerasi=Conotrachelus nenuphar 14, 16
Riparia riparia, enemy of plum curculio 154
Rose-beetle, Fuller's. (See *Aramigus fulleri.*)
Sigalphus curculionis. (See *Triaspis curculionis.*)
Snout-beetle, imbricated. (See *Epicærus imbricatus.*)
Soda, sulpho-arsenate, against plum curculio 188
on peaches 206
and self-boiled lime-sulphur against plum curculio 188
injurious effects on peach 207
Sphenophorus parvulus, host of *Myiophasia ænea* 149
Spraying with arsenicals against plum curculio 178–185
on apple, early experiments. 189–193
experiments by Bureau of Entomology 193–200
cherries and plums 215–218
peaches 202–215
Strawberry, place of oviposition by plum curculio 33
Swallow, bank. (See *Riparia riparia.*)
Temperature, relation to time of appearance of plum curculio in spring 118–120
Tent caterpillar, spraying with arsenicals 201
Thelairodes basalis=Cholomyia inæquipes 150
Thersilochus conotracheli, parasite of plum curculio 147–148
Thrips, enemy of plum curculio 152
Thrush, hermit. (See *Hylocichla g. pallasi.*)
Tmetocera ocellana. (*See* Bud moth.)
Toad, enemy of plum curculio 154
Triaspis curculionis, parasite of *Anthonomus grandis* 143
Balaninus sp 143
Conotrachelus affinis 143
elegans 143
juglandis 143
plum curculio 142–146
stalk-borer on Ambrosia 143
Trichobaris trinotata 143
var. *rufus*, parasite of plum curculio 146–147
Trichobaris trinotata, host of *Triaspis curculionis* 143
on eggplant 143
"Turk," common name for plum curculio 14
Veery. (See *Hylocichla fuscescens.*)
Vireo, yellow-throated. (See *Lanivireo flavifrons.*)
Zamelodia ludoviciana, enemy of plum curculio 154
Zinc cyanid against plum curculio 206
oxid against plum curculio 206
sulphid, injurious effects on peach 207

○

U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF ENTOMOLOGY—BULLETIN No. 104.
L. O. HOWARD, Entomologist and Chief of Bureau.

THE FIG MOTH.

BY

F. H. CHITTENDEN, Sc. D.,
In Charge of Truck Crop and Stored Product Insect Investigations.

REPORT ON THE FIG MOTH IN SMYRNA.

BY

E. G. SMYTH,
Entomological Assistant.

Issued November 4, 1911.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1911.

FIG. 1.—SMYRNA FIG FROM NEW YORK CITY, SHOWING INJURY BY FIG MOTH (EPHESTIA CAUTELLA). (ORIGINAL.)

FIG. 2.—DRIED FIGS INFESTED WITH FIG-MOTH LARVÆ, SHOWING HOLES BORED THROUGH SKINS, ABUNDANT EXCRETA ADHERING TO FIGS, AND SINGLE LARVA AT RIGHT. (ORIGINAL.)

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 104.
L. O. HOWARD, Entomologist and Chief of Bureau.

THE FIG MOTH.

BY

F. H. CHITTENDEN, Sc. D.,
In Charge of Truck Crop and Stored Product Insect Investigations.

REPORT ON THE FIG MOTH IN SMYRNA.

BY

E. G. SMYTH,
Entomological Assistant.

Issued November 4, 1911.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1911.

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, *Entomologist and Chief of Bureau.*
C. L. MARLATT, *Entomologist and Acting Chief in Absence of Chief.*
R. S. CLIFTON, *Executive Assistant.*
W. F. TASTET, *Chief Clerk.*

F. H. CHITTENDEN, *in charge of truck crop and stored product insect investigations.*
A. D. HOPKINS, *in charge of forest insect investigations.*
W. D. HUNTER, *in charge of southern field crop insect investigations.*
F. M. WEBSTER, *in charge of cereal and forage insect investigations.*
A. L. QUAINTANCE, *in charge of deciduous fruit insect investigations.*
E. F. PHILLIPS, *in charge of bee culture.*
D. M. ROGERS, *in charge of preventing spread of moths, field work.*
ROLLA P. CURRIE, *in charge of editorial work.*
MABEL COLCORD, *in charge of library.*

TRUCK CROP AND STORED PRODUCT INSECT INVESTIGATIONS.

F. H. CHITTENDEN, *in charge.*

H. M. RUSSELL, C. H. POPENOE, WM. B. PARKER, H. O. MARSH, E. G. SMYTH,[a] THOS. H. JONES, M. M. HIGH, FRED A. JOHNSTON, *entomological assistants.*
I. J. CONDIT, *collaborator in California.*
P. T. COLE, *collaborator in tidewater Virginia.*
W. N. ORD, *collaborator in Oregon.*
MARION T. VAN HORN, *preparator.*

---

[a] Transferred to cereal and forage insect investigations, Mar. 15, 1911.

LETTER OF TRANSMITTAL.

United States Department of Agriculture,
Bureau of Entomology,
Washington, D. C., August 2, 1911.

Sir: I have the honor to transmit herewith the manuscript of a bulletin dealing with the fig moth. It consists of two papers, the first, entitled "The Fig Moth," by Dr. F. H. Chittenden, in charge of truck-crop and stored-product insect investigations, and the second, entitled "Report on the Fig Moth in Smyrna," by Mr. E. G. Smyth, entomological assistant.

While the fig moth has been known in this country as a pest since 1897, at which time a short preliminary paper was published in regard to it in Bulletin No. 8, new series, of this bureau, it was not until 1908 that the insect attracted any great attention. It had by that time invaded mills of various kinds, including rice mills in the Southern States, and in these situations it is now quite a serious pest. In 1909 and 1910 thousands of dollars worth of figs were condemned by the Bureau of Chemistry under the law regulating the sale of adulterated or deleterious foods and drugs. This led the importers and dealers in Smyrna figs to request an investigation of the matter by the United States Department of Agriculture.

In pursuance of your directions Mr. E. G. Smyth visited Smyrna in Asia Minor to investigate the local conditions under which this important industry is carried on, and his report is embodied in the second paper of this bulletin. The work upon which the first paper is based was conducted by Dr. Chittenden in person, and this portion of the bulletin gives a very full general account of the insect.

The life history and food habits of the fig moth, as it occurs in the District of Columbia, where the weather in midsummer is not materially cooler than in Smyrna, have been thoroughly worked out, while the recommendations as to remedies are based upon actual experiments.

Particularly valuable among the remedies suggested would be the treatment of figs in specially prepared fumigatories located a short distance from the "khans" or buildings in which the figs are stored.

It has been found that bisulphid of carbon in a high temperature, ranging between 90° F. and 100° F., will kill practically all fig moths with an exposure of 24 hours, even with less of the fumigant than is usually advised.

I recommend the publication of these papers as Bulletin No. 104 of the Bureau of Entomology at the earliest possible moment, since there is urgent demand for this information on the part of merchants and growers interested in the culture, shipment, and sale of Smyrna figs.

Respectfully,

L. O. Howard,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

	Page.
The fig moth (*Ephestia cautella* Walk.) .... *F. H. Chittenden*..	9
Introduction	9
Description of the species	10
Characters of the moth	10
Technical description of the moth	11
Distribution	11
Description of the earlier stages	11
The egg	11
The newly hatched larva	12
The full-grown larva	12
The cocoon and pupa	13
Literature and history of the species in Europe	13
History of the species in America	14
List of food materials	19
Inspection of Smyrna figs in the Bureau of Entomology	21
Inspection of samples of figs from the Dried Fruit Association	25
Average infestation of figs entering the port of New York	28
Life-history notes on the fig moth	28
Oviposition	28
The transformation to pupa	29
The life cycle	29
Natural enemies	30
Methods of control	32
Preventives	33
Heat as a remedy	34
Methods of packing figs as a protection against insect attack	35
Experiments with fumigants at a high temperature	36
Bisulphid of carbon	36
Hydrocyanic-acid gas	37
Summary	38
Bibliographical list	39
Report on the fig moth in Smyrna .... *E. G. Smyth*..	41
Sources of infestation	41
Occurrence of larvæ in the orchard	42
Eggs on figs on the trees	42
Moths in the orchard	43
Oviposition on figs drying on the "serghi"	44
Percentage of infestation on the "serghi"	45
Infestation in fig depots	46
Infestation in freight cars	46
Infestation in bazaars in Smyrna	47
Infestation in the "khans"	47
Infestation in steamers during ocean transit	48
The principal source of infestation	48

Report on the fig moth in Smyrna—Continued. Page.
Methods of control ... 49
Destruction of the earlier broods of the moth ... 49
Protection of drying figs ... 50
Excluding moths from fig "depots" ... 50
Destruction of eggs on figs ... 50
Discontinuing the retention of figs inland ... 51
Elimination of larvæ in the khans ... 52
Experiments in the khans ... 53
Destruction of larvæ by vacuum treatment ... 53
Ridding figs of larvæ by steam ... 54
Scalding figs in hot water to kill larvæ ... 55
Apparatus for sterilizing with hot air ... 59
Success of hot-air treatment in killing larvæ ... 62
Practicability of sterilizing all figs in Smyrna ... 63
Summary of preventive measures ... 65

ILLUSTRATIONS.

PLATES.

Page.

PLATE I. Fig. 1.—Smyrna fig from New York City, showing injury by the fig moth (*Ephestia cautella*). Fig. 2.—Dried figs infested by fig-moth larvæ .... Frontispiece.

II. Pile of figs in fig depot, one of the primary places of infestation..... 32

III. Fig. 1.—Figs packed by string method. Fig. 2.—Some of same figs to illustrate larval infestation 36

IV. Package of Smyrna figs, packed in Turkey for American trade, according to layer method 36

V. Fig. 1.—Extensive fig orchards in valley of Caystrus River, Asia Minor. Fig. 2.—Typical Smyrna fig orchard in Meander Valley, Asia Minor 42

VI. Fig. 1.—The crude form of "serghi" employed in most orchards for drying figs. Fig. 2.—Near view of figs drying on "serghi," Nazli, Asia Minor 44

VII. Fig. 1.—"Serghi" of reeds laid in long rows, used in large orchards. Fig. 2.—Uruk girls spreading figs on "serghi" to dry, Tchifte Kaive, Asia Minor 44

VIII. Fig. 1.—Team of water buffalo, with driver and Turkish cart, often used for carrying figs. Fig. 2.—Figs arriving at a "depot," brought from orchard on horseback by peasant who grew them, Tchifte Kaive, Asia Minor 46

IX. Fig. 1.—Figs of different grades being mixed in "depot" of interior, and resacked for shipment to Smyrna. Fig. 2.—Camel caravan conveying figs from a "depot" to railroad station in interior of Asia Minor 46

X. Fig. 1.—Closed railroad car or "wagon," used in transporting figs from interior of Asia Minor to Smyrna. Fig. 2.—An indoor fig bazaar at Smyrna 48

XI. Fig. 1.—Pile of refuse figs in a Smyrna "khan." Fig. 2.—Greek women grading the refuse figs in a Smyrna "khan" 48

XII. Fig. 1.—Large "paciale" of natural (dried) figs, ready to sack for export, in a fig "khan" in Smyrna. Fig. 2.—Natural (dried) figs being watered and mixed 48

XIII. Fig. 1.—Thousands of bags of natural (dried) figs in a Smyrna "khan" for export to America. Fig. 2.—Skeleton cases of Smyrna layer figs bound for America in hold of Mediterranean steamer at Genoa. 48

XIV. Fig. 1.—A hand vacuum machine for extracting air from jars of figs, and its operator. Fig. 2.—Oven for sterilization of figs by dry heat 52

XV. Fig. 1.—Steam disinfecting closet. Fig. 2.—Interior of steam disinfecting closet 52

Page.

PLATE XVI. Fig. 1.—Copper boilers and galvanized strainers used for sterilizing figs in a Smyrna "khan." Fig. 2.—Interior of oven for drying trays of figs which have been sterilized by boiling, used in a fig "khan" in Smyrna 56

TEXT FIGURES.

FIG. 1. The fig moth (*Ephestia cautella*): Adult, larva, and details 10
2. The Mediterranean flour moth (*Ephestia kuehniella*): Larva 10
3. *Hadrobracon hebetor*, a parasite of the fig moth: Adult female and antenna of male 31
4. *Omorga frumentaria*, a parasite of the fig moth: Adult 31

THE FIG MOTH.

By F. H. Chittenden, Sc. D.,
In Charge of Truck Crop and Stored Product Insect Investigations.

INTRODUCTION.

Prominent among the many species of insects which are being constantly shipped to this country from abroad is the fig moth (*Ephestia cautella* Walk.). Since 1908 this species has attracted much attention by its occurrence in various edibles in different portions of the United States, as well as in the mills of Texas and Louisiana. It has been concerned, with other insects, in considerable damage to rice, and reports are available of similar injury to flour and corn meal and other mill products, cotton seed, various other dried seeds and fruits, and other stored foods.

In the late fall of the year 1909, however, the species attained unusual prominence from the fact that the Bureau of Chemistry, working in pursuance of legislation on the pure food and drug law, seized numerous consignments and cargoes of figs in New York, Philadelphia, Boston, and some other large cities. This brought to light the fact that a very large portion of imported figs, especially such as are shipped from Smyrna, which port ships about 90 per cent of its total output to the United States, is found to be badly infested when reaching America. The dried figs in the market are frequently found to contain from 15 to 50 per cent and even higher percentages of infested fruit. These estimates, chiefly by the Bureau of Chemistry, are based partly on the presence of the insect, but largely on that of its excreta. The gravity of the situation became such in 1909 and 1910 that thousands of dollars' worth of figs were condemned, leading the dealers in Smyrna figs to request an investigation of the matter by the United States Department of Agriculture.

In accordance with the Secretary's direction, the following account of the fig moth has been drawn up, including a report, by Mr. E. G. Smyth, on the occurrence of the insect in what is perhaps its native home—Smyrna, Turkey in Asia. The writer's article deals primarily with the insect as a pest in stored products in America.

DESCRIPTION OF THE SPECIES.

Before proceeding to the description of the fig moth it should be stated that according to recent classification it belongs to the lepidopterous family Pyralidæ and subfamily Phycitinæ. Some writers give this subfamily full family rank and therefore call it Phycitidæ.

As to nomenclature, the species is now recognized as *Ephestia cautella* Walk., with the following synonyms: *cahiritella* Zell., *passulella* Barr., and *desuetella* Walk.

CHARACTERS OF THE MOTH.

This moth looks suspiciously like the congeneric *Ephestia kuehniella* Zell., the Mediterranean flour moth, and like *E. elutella* Hübn., as will be noticed by reference to the illustration (fig. 1), being of

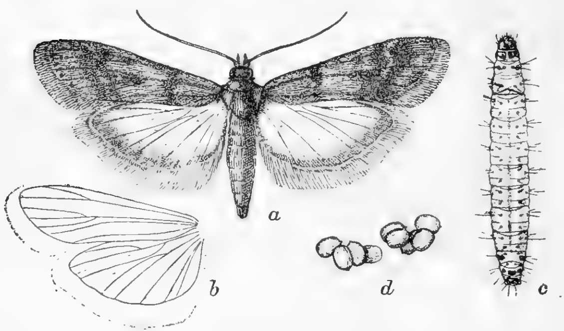


FIG. 1.—The fig moth (*Ephestia cautella*): *a*, Moth with expanded wings; *b*, denuded wings, showing venation; *c*, larva, full grown, dorsal view; *d*, two egg masses. *a*, *b*, *c*, About 4 times natural size; *d*, more enlarged. (Original.)

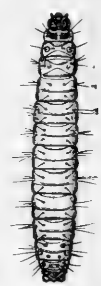


FIG. 2.—The Mediterranean flour moth (*Ephestia kuehniella*): Larva, dorsal view. (Author's illustration.)

a similar gray color, but it may be readily known from the former by the strong subdorsal line of the cilia of the hind-wings. The markings of the fore-wings are much more suffused than in the other two species, and the line across the basal third is whitish, more nearly straight, and bordered by a prominent, dark, suffused band. In the others this line is irregularly dentate or zigzag. The color of the fore-wings varies, some individuals being fawn color with scarcely any dark markings, while Ohio and District of Columbia series are considerably darker than either *kuehniella* or *elutella* and in some cases are very strongly suffused with reddish scales.

The following technical description of the moth is copied from Barrett:[3][a]

[a] Numerals in superior type refer to corresponding numbers in the bibliographical list, p. 39.

TECHNICAL DESCRIPTION OF THE SPECIES.

Fore-wings narrow, especially at the base, costa less arched than in the preceding species [*ficulella* Barr.]. Costal lappet with a broad tuft of scales. Fore-wings pale fuscous with a yellowish tinge, scales large and coarse, and easily rubbed off. First transverse line at one-third the length of the wing, fuscous, ill-defined, straight, and very slightly oblique. Second line parallel with the hind margin, pale, faintly edged with fuscous, often nearly obsolete. Usual two dots on the disc oblique, fuscous, hardly discernible, cilia yellowish-fuscous. Hind-wings white, with scattered fuscous scales, and a faint brown margin, cilia white. Male with one ochreous tuft at the base. Head, antennæ, palpi, thorax and abdomen yellowish fuscous. Antennæ simple beyond the thick basal joint.

The wing expanse is from 14 to 20 millimeters.

DISTRIBUTION.

Like other species of the genus, the fig moth is supposedly of Asiatic origin. Judging from its abundance in Turkey in Asia that country would seem to be what Packard terms the insect's "metropolis;" in other words, its original or acquired locality of greatest abundance. However that may be, it is now, judging by published and office records, as well distributed as perhaps any of the Phycitidæ with the exception of the Indian-meal moth (*Plodia interpunctella* Hübn.), which is more nearly omnivorous in habit, and, therefore, more nearly universal in occurrence.

The known distribution includes Ceylon; Egypt; Smyrna, Turkey in Asia; China; Cochin China; Japan; Siberia; England; south-central and southern Europe; Venezuela; Guayaquil, Ecuador; Jamaica and Trinidad, British West Indies. In North America it is known in the following localities: Montreal, Canada; Milton, Mass.; New York, N. Y.; Washington, D. C.; Milwaukee, Wis.; Calla, Ohio; Hershey, Pa.; Guthrie, Okla.; Wichita, Kans.; Miami, Fla.; New Orleans, Morse, and Lake Arthur, La.; Galveston, Dallas, Sherman, San Antonio, New Braunfels, Fort Worth, Wichita Falls, Beaumont, Houston, McKinney, and El Campo, Tex.

DESCRIPTION OF THE EARLIER STAGES.

The egg.—The egg is whitish when first laid but turns after a few days to ochreous and, just before hatching, often, in parts, to orange. In form it is oval, sometimes approaching oblong-oval, often with a distinct nipple at one extremity. Its surface is subopaque, strongly rugose; the longitudinal rugæ are coarse, short, arranged in rather irregular alternating rows of about 24 and, with the transverse smaller rugæ, give a somewhat reticulated appearance. The smaller rugæ are fine and cilia-like, radiating from the longitudinal ones.

The egg is subject to considerable variation in form. Measurements of five eggs showed the following average:

Length, 0.33–0.38mm.; width, 0.22–0.32mm.

Two groups of eggs are shown, highly magnified, at fig. 1, *d*.

The newly hatched larva.—The larva when first hatched is delicate, white in color, sparsely hairy, and is about a millimeter long, being about six times as long as wide when contracted. It is widest at the head, which is light brown. The eyes are small and nearly black. The first thoracic segment is nearly as wide as the head, perceptibly darker than the remaining segments, which are clear white and less than four-fifths as wide as the head. The legs are long, particularly the thoracic ones.

The full-grown larva.—The full-grown larva or caterpillar is of nearly the same form as that of the Mediterranean flour moth, *Ephestia kuehniella* (see fig. 2.), and faintly marked individuals would easily be mistaken for that species. It differs chiefly in its smaller size, being a third smaller than the flour-moth larva, in its darker color, and in its more prominent piliferous dots, which, with the pink or flesh tints which are arranged longitudinally along the dorsum, give it a distinctly striated appearance.

DESCRIPTION.

The full-grown larva is cylindrical, about six times as long as wide, generally of similar form to *E. kuehniella*. Ground color dirty whitish, very pale greenish, or very light buff, with an overlay of rather dull pinkish tints arranged in more or less definite longitudinal rows on the dorsal surface. Surface very finely granulate. Head about half the greatest width of the body, ochraceous or cinnamon rufous in color, darkening toward the mouthparts. Thoracic plate (cervical shield) of similar form to that of *kuehniella* but faintly tinged with blackish anteriorly and much darker, nearly black posteriorly. Piliferous dots or warts, and particularly the other markings, nearly as in *kuehniella*, but all dots of darker color, nearly black, larger, and more conspicuous. Ventro-lateral and ventral rows quite conspicuous, the four pairs of rows presenting, with the banded pink coloring of the dorsal surface, a distinctly striated appearance. Posterior fold of abdominal segments not noticeably smaller than anterior.

Length, 9.5–12.5 mm.; width, 6.2 mm. In appearance more robust than *E. kuehniella* when contracted and when at rest, and more slender when extended. A larva 10 mm. in length will extend to 12.5 mm. and contract to 8.5 mm.

The larva is illustrated in figure 1 at *c*, about four times natural size, and that of *E. kuehniella* is reproduced in figure 2 for comparison.

The larva exhibits much the same variation in color as does that of *E. kuehniella*, the quality of food playing no perceptible part in regulating or even indicating the hue. The ground color ranges from whitish to yellowish and greenish, with flesh tints arranged longitudinally, somewhat like stripes, along the dorsal surface.

In some individuals the flesh tints are almost wanting; in others they are so marked as to give the impression of a body color of pink and even purplish. Individuals reared from the interior of English walnuts, where they were concealed from the light, were as a rule lighter in color than those that had fed, in a more exposed position, upon flaxseed, and the latter were also more strongly marked with flesh color.

The cocoon and pupa.—The cocoon of the fig moth varies according to its location. The specimens that "spun up" in corn meal and were covered with particles of the meal varied from 10 to 20 mm. in length, outside measurement, but were only about 6 mm. in length, inside measurements. Cocoons "spun up" without the covering measured from 10 to 12 mm. in length and were 3.5 mm. wide. Inside they are lined with exceedingly fine, delicate white silk.

The pupa, as would naturally be expected, resembles closely that of *E. kuehniella*, but is of a lighter color and smaller, measuring between 7 and 8 mm. in length, and is about four times as long as wide.

LITERATURE AND HISTORY OF THE SPECIES IN EUROPE.

This species was first described by Francis Walker in 1863,[1a] and later redescribed by Zeller in 1867,[2] from two examples from Cairo, Egypt, as *Ephestia cahiritella*. It was subsequently redescribed in 1875 by Barrett,[3] who called it *E. passulella* from its occurrence in the so-called Corinthian raisins or currants ("*Passulæ corinthiacæ*"). This is a fruit of a small variety or species of grape, in this country universally called "currants." To distinguish it from other species that infest dried fruits the writer suggested calling it, after the later Latin name, the dried-currant moth.

Walker and Zeller in their descriptions say nothing of the habits of this moth, and Barrett said only that it was "locally common in currant warehouses" in London and that it fed upon dried currants. He observed, however, that it had the singular hovering flight, common to the Indian-meal moth (*Plodia interpunctella*) and *Ephestia elutella*, that it was "exceedingly active and lively, flying freely in the afternoon," and that "the air often seemed alive with these insects." In 1882 William Buckler[4] made some study of the habits of the species, which he fed upon the "locust bean" of commerce, describing the eggs, larva, pupa, and cocoon. During the same year, and in the same periodical,[5] Mr. George T. Porritt published a supplementary note expressing the opinion that the species is double brooded, and mentioned dried figs as a food material. To this the same writer added the observation that the larvæ remained in their

[a] The small figures refer to corresponding figures in the bibliographical list, p. 39.

cocoons during the winter and changed to pupæ, without feeding, in the spring.[6] Again in this same publication Mr. Edw. A. Atmore[7] gave an interesting account of the occurrence of this species and *E. ficulella* in a cargo of "decorticated cotton cake" from Galveston, Tex. This cargo had become wet and heated on the voyage and when the ship arrived at King's Lynn, England, and the hatchways were opened, a cloud of the moths flew out, "settling on everything and everybody near." Owing to the superabundant heat induced by the wetting of the cakes the moths had issued prematurely. When exposed to the cold of February they were benumbed and fell upon their backs. In 1885 Mr. E. L. Ragonot[8] furnished some new localities for the species and in 1890 Mr. Richard South,[9] in a paper on British Lepidoptera, republished Barrett's description, bringing together the bibliography and known distribution with a plate figure of the adult. During 1891 Mr. W. T. Pearce[10] wrote a short note on this species, stating that "the larva forms silk-lined passages through dried currants and may be found in almost any case of them; there appears to be a constant succession of broods throughout the year." He also mentioned the occurrence of a small black ichneumon parasite. In 1895 Mr. Edward Meyrick, in his Handbook of British Lepidoptera,[12] furnished a brief description of the moth, with distribution.

HISTORY OF THE SPECIES IN AMERICA.

The first record of the injurious occurrence of this moth in American literature was made by the writer in 1897[13] and appeared in the form of a short preliminary paper entitled, "A storehouse moth new to the United States, with notes on other species." An account was given of the observed occurrences of the species in America, together with brief descriptive and other notes and illustration of the eggs, larva, moth, and wing venation.

The first recognition of the moth in this country, however, dates back to 1884, when, as previously stated, the species was observed in England in cotton cake from Galveston, Tex. Of course there is here the possibility that the cotton cake became infested en route, but it is more probable that the material was already infested before shipment.

When we consider the wide distribution and omnivorous habits of this species in America at the present time, there is little doubt that it was introduced many years before the first recorded date, 1884; and it also seems likely, considering its abundance, that it has to a certain extent replaced *Ephestia elutella* if we assume that the latter was introduced at a much earlier date, as seems probable.

During September and October, 1893, moths were issuing freely and flying about cases of cacao beans exhibited by Jamaica and Vene-

zuela at the Columbian Exposition, where the species was first observed by the writer. There were hundreds of bags and open boxes and jars of cacao beans exhibited by most of the tropical and semitropical countries, many of which were more or less affected by the larva of this insect. It seems probable that this species has been introduced wherever cacao-bean cultivation thrives and wherever chocolate is manufactured, judging by the fact that so many exhibits showed signs of infestation.

At the same exposition it was found to have bred in dried gallnuts, labeled "gobaishi," exhibited by Japan.

In October, 1895, a lot of flaxseed meal that was badly infested with the larva of this moth, was received from Calla, Ohio. The meal was transferred to a jar and as the larvæ worked toward the sides it could be seen that they were present in great numbers, and it was necessary to add fresh meal in order to keep them supplied with sufficient food. Long after the larvæ of *Plodia interpunctella*, which were present in vivaria under similar conditions, had for the most part left their food in search of places for pupation, these caterpillars were still active, although kept in a very cool room at an average temperature of about 60° F. Upon moving the jar an explanation of this was offered. The bottom and sides of the jar, a thick glass fruit "can" in this case, were quite warm.

In December of the same year specimens of this insect in different stages were received from the Atlanta exposition in cacao beans from Venezuela, South America, and from Jamaica and Trinidad, British West Indies, and in tonka beans (*Dipteryx odorata*) from Guayaquil, Ecuador. During this and following months in 1896 several pounds of English walnuts more or less affected by the larva were obtained by the writer from various local merchants and street venders. In some lots nearly every nut had been ruined by the caterpillars. Their presence is manifested by the lighter weight of the nut and its stem end usually shows a small hole or two that has been used either for entrance or exit, and a few particles of webbed-up excrement will sometimes be found accumulated at this point. If such a walnut be opened, its interior, if it be badly infested, will be found filled with larval excrement, the particles composing the mass being united by webbing.

The writer has also reared the species from pecan nuts and has seen specimens reared from peanuts.

Figs purchased of street venders in different parts of the city at about this time were found to be very generally affected by this species.

The following June (1896) the Bureau of Chemistry transmitted specimens of the larvæ in a sample of pearl hominy purchased in open market in this city. The larvæ were "spun up" in the same manner

as are those of *Ephestia kuehniella*, the cocoon thus formed looking much like that of the flour moth. June 6 the first moth issued, and at the same time larvæ were discovered at work in an open bottle of corn meal standing on the writer's office desk. The meal had been used for observations on other insects and it had not been necessary to keep it covered. A moth of this species had escaped from an open box of nuts, laid its eggs in the meal, and this was the result. Subsequently moths were reared in great numbers, this accidental evidence of the cereal-feeding habit of the species proving more satisfactory than a purely artificial experiment would have been.

During July a larva, from the same source as the ones found in the corn meal, was discovered at work in a small box of duplicate specimens of moths of its own species. It had ruined seven specimens by eating away their abdomens and in some cases a portion of the wings. In the rearing jars evidence of this same habit had previously been noticed.

Other stray larvæ were found breeding in the berries of asparagus, which they appeared to relish as much as any other food material. Moths also bred from stored corn at this time in two instances.

November 12, 1896, the late Dr. James Fletcher sent specimens of the larvæ breeding in linseed meal received from Montreal, Canada.

On June 2, 1898, Mr. J. L. Sheppard, Charleston, S. C., sent specimens of the larva in its webs in cleaned or white rice, with information that nothing injures the sale of their domestic rice as do these larvæ. During the previous year they appeared in rice toward th last of the summer, many of them at that time being quite large and measuring upward of half an inch in length.

September 21 of the same year Mr. Frank Bates, an entomologist, residing at South Braintree, Mass., wrote that the larvæ do much damage to chocolate unless great precautions are taken, and that he had known the owner of a chocolate company at Milton, Mass., to order several tons of chocolate shells, so-called, valued at about $200 a ton, to be thrown into the furnace and destroyed, as he would not risk any depreciation of his goods. He had occasionally seen "shells" in bulk at small grocery stores almost matted together by the silken threads thrown out by these larvæ, so that a mass as large as a man's head could be lifted from the barrel and the larvæ would be seen crawling out of the mass. "This," he writes, "gives us the evident warning never to purchase cocoa shells except those done up in pound cartons." Our correspondent stated that he never employed for his personal use any manufactured chocolate except that manufactured by one firm, which he knew to be of the best quality, since the owner did not permit any shells to be sold in bulk.

During 1907 Mr. Perry D. Preston, Isthmian Canal Commission, Canal Zone, Isthmus of Panama, wrote from Empire, sending speci-

mens of Spanish bean or chick-pea imported from Spain, where they are known as "garbanzos," showing injury by this species. November 23, Mr. P. J. Wester, Miami, Fla., sent larvæ in the seed of *Cecropia palmata.* From this lot the first larva transformed to pupa December 7, and the adult issued December 27, or in 20 days; this being an exceptionally long period for the pupal stage. An adult issued January 4, 1908. This sending is of peculiar interest inasmuch as it points to a possible wild food plant, and to the fact that in a tropical climate like that of Miami, Fla., the moths may issue throughout the winter. December 4, a larva of this species was received from an unknown locality in China in the fruit of the jujube tree (*Zizyphus jujuba*).

During 1908 this species was received in the larval condition in flour and meal from Sherman, Tex., sent by Mr. D. K. McMillan, and through the Bureau of Plant Industry in peanuts from Saigon, Cochin China.

In 1909 this insect was received from many sources. Larvæ were collected in a number of large cities and milling towns in Texas and Louisiana by Mr. McMillan. The records of the bureau also show that on June 15 it was concerned with other insects in damaging rice to the extent of many thousands of dollars a year at New Orleans, La. June 19 it was reported by Prof. Harper Dean as common in meal from San Antonio, Tex. June 21 it was received in flour from a mill in San Antonio, Tex. Later it was received in flour and other mill stuff from different mills in San Antonio and New Braunfels, Tex. It was present in cottonseed mills at Galveston, Tex., and in rice in a rice mill at Morse, La. In July it was collected by Mr. McMillan in flour at Fort Worth and Wichita Falls, Tex., in cottonseed meal from Guthrie, Okla., and in flour from Wichita, Kans., where it was troublesome in bakeries. Specimens were also received, July 19, from Hershey, Pa., where it was injurious to dried currants.

October 9 Mr. W. R. Beattie furnished specimens in seed peanuts from Africa. In November and December Mr. McMillan furnished larvæ in broken rice from Beaumont, Tex., in various dried seeds and grains from Houston, Tex., and from screenings taken from a rice mill at Lake Arthur, La.; in a lot of broken rice called "brewers' stock" the insect occurred in great numbers, badly infesting the material. In one case nearly 100 sacks of screenings in one mill were badly affected.[a]

The above records refer chiefly to the occurrence of this species in rice mills, although there are some records also of occurrence in flour mills, e. g., in Dallas and McKinney, Tex., and of injury to dried fruits, etc.

---

[a] In some of these cases other insects were present, such as the rust-red flour beetle (*Tribolium navale* Fab.) and the lesser grain borer (*Rhizopertha dominica* Fab.).

Beginning with October 14, 1909, the bureau received during the month, almost daily, samples of Smyrna figs infested by this species from New York City, Philadelphia, and Boston. These were furnished by the Bureau of Chemistry by request, and were in most cases in Smyrna figs seized by that bureau because of "worminess"[a] or because they consisted "in whole or in part of a filthy, decomposed, or putrid animal or vegetable substance, or any portion of an animal unfit for food." One sample of infested Cartrevas figs was received.

From the same source this insect was also received in shelled peanuts and dried apples from Boston, Mass.

During 1910 a milling company at Crowley, La., sent this larva in rice, bran, and cottonseed meal, with complaint that it occurred in immense numbers and apparently did trouble by working in the sacks. During November and December of that year samples of this insect and its work were received from Mr. E. G. Smyth, collected by him at Smyrna, Turkey in Asia.

During January and February, 1911, numbers of samples of figs were examined which showed the presence of this species either as dead larvæ or excreta. A few living larvæ were seen.

In writing of the occurrence of this species in Texas and Louisiana Mr. McMillan says that in his experience it is frequently found in mills, warehouses, dock sheds, feed stores, groceries, and other places where ground foodstuffs are kept. It was observed in small numbers in drug stores and in kitchen closets and cupboards. While the moths were seen in nearly all the flour mills visited in Texas, the larvæ were not found in excessive numbers, and the millers did not complain of serious trouble. Slight accumulations of webbed material had to be removed at times from some mill spouts, but no case has been reported of choking up as with *Ephestia kuehniella;* in fact few millers have made any observations upon this species or distinguished it from other flour and meal moths. He stated further:

It seems to prefer the coarser and sweeter ground products to flour, and the moths are more frequently found in bran and middlings, and around the spouts carrying these materials, than associated with straight flour. Among substances most commonly infested may be listed cottonseed meal, rice bran and polish, mill chop and middlings, wheat flour and bran, corn meal and corn bran or hulls, oatmeal, flaxseed meal, and occasionally breakfast cereals in private houses and groceries.

Larvæ have been less frequently seen than adults, though their webs in small masses mingled with food materials and excrement are often abundant when they have been allowed to accumulate undisturbed for some time. In a feed and grain warehouse at Galveston, Tex., the top and outside tiers of bags hold-

[a] In some instances a parasite, probably *Limnerium ephestiæ* Ashm., and a few specimens of other species of insects, accompanied the samples. Chief among these latter were the saw-toothed grain beetle (*Silvanus surinamensis* L.), one of the sap-beetles (*Carpophilus hemipterus* L.), a scavenger which attacks neglected fruits, two species of ants, and the mite *Carpoglyphus passularum* Hering.

ing rice bran were covered in places with a thin layer of webs and many cocoons were seen around the edges of sacks and in folds of the cloth. The larvæ had not penetrated more than half an inch into the contents. In a flour mill here several partly filled barrels of old corn bran had been infested for some time, and the surface material was covered by a layer of hulls and matted webs about 2 inches thick, beneath which the larvæ did not seem to penetrate. They were also found on bags of cottonseed meal and rice bran on one of the wharves and in the cracks between the planks at one of the docks at New Orleans, La., where they were feeding on the cottonseed meal held by cotton lint.

The adults have been frequently seen mating or at rest in any convenient position upon sacks and in other situations in mills and elsewhere. Adults at rest have the front edges of the wings curved slightly inward and the wings in general held closely around the body instead of spread slightly and flattened upon their resting place as with *Ephestia kuehniella* and especially *Plodia interpunctella*. The moth is rather slow in flight. It remains at rest practically continuously during the day unless disturbed, but has often been seen flying in dark parts of buildings and at evening.

LIST OF FOOD MATERIALS.

In time, as observers become familiarized with this moth, it will doubtless be found to have nearly the same omnivorous tastes as the Indian-meal moth. The following list of its observed food materials is appended:

Cacao beans or chocolate nuts (*Theobroma cacao*); prepared chocolate; tonka beans (*Dipteryx odorata*); English walnuts, or, more properly speaking, Persian walnuts (*Juglans regia*); pecans; peanuts or ground nuts (*Arachis hypogæa*); figs; chick-pea (*Cicer arietinum*); wheat flour; rice and rice preparations and bran; Indian corn and corn meal and other preparations; hominy; oatmeal; cotton seed and meal and cotton-oil cakes; asparagus berries; evaporated and dried apples; linseed or flaxseed meal; Corinthian currants (*Vitis corinthiacæ*); the seeds of *Zizyphus jujuba;* the fruit of *Cecropia palmata;* "locust beans" of commerce; wild gallnuts; and dried insects.

Taken all in all, it seemed at one time that it was as an enemy of chocolate that this species was most entitled to serious consideration.

Cacao beans are injured seriously. The beans are often badly damaged and webbed together with silk and covered with excrement and other detritus. Again, a bean may have no visible signs of insect work upon it other than the presence of a little hole, sometimes nearly closed with silk, but such infested seeds are invaribly lighter in weight and when opened are found to be filled with more or less webbed-up excrementitious matter which can not be otherwise than deleterious when taken as food into the human system. Great quantities of cacao beans are consumed in the form of confectionery and in cake, ice cream, and soda water, and in the beverages called cocoa

and chocolate. Even if we could ignore the unwholesomeness of eating or drinking substances containing the ordure and dead bodies of insects, the thought of using such materials in our food and beverages is repulsive, and yet the writer was credibly informed in 1893 that infested cacao beans were used not only for such purposes, but that when infested they brought precisely the same price per pound as the clean article and were not considered by the manufacturers in any degree inferior for their uses.

The fresh beans have an agreeable, nutty, slightly bitter flavor, but insect-infested nuts are more bitter and sometimes have a decidedly disagreeable taste, and there is at least a suspicion that the bitterness of the cheaper forms of so-called pure chocolate, sold in compressed cakes and in powder form, may be due largely to the work of the Ephestia larvæ and the possible decomposition that would be induced from their attack.

It will be readily noticed by perusal of the earlier records of the occurrence of the fig moth in the United States that there was apparent fondness shown for material containing an abundance of oily matter, such as various nuts, cotton seed, flaxseed, and the products of Indian corn, in all of which it bred freely. It was a matter of some surprise, therefore, to find later that it bred quite as freely on rice, which contains little oily matter, as also to learn that it had already established itself as a rice pest in the Gulf States. Doubtless in time it will be found to feed upon most if not all of the cereals, if we except such as unhulled oats and rye, the hulls of which are difficult to penetrate unless first attacked by some other insect.

It is still early to predict the future of this moth as a pest in the United States. Perhaps in the course of time it may be introduced from the Gulf region northward, but in spite of appearances which indicate that it is perfectly capable of becoming exceedingly troublesome, it is doubtful if it will ever become so serious a pest as is the Mediterranean flour moth. It is practically established in the South, but its increase in the North is problematical.

Some remark should be made in regard to the injury accomplished by this insect to figs. The main injury is accomplished before the figs reach America, the principal damage being effected en route from the orchards to our American ports. Examination in this office of many samples of imported figs furnished by the Bureau of Chemistry seldom showed the larvæ or "worms" in any number and few were alive; but in badly infested samples the excreta were very much in evidence and it is due more to the presence of the excreta and "worm holes" than to the presence of the "worms" themselves that the figs are deemed unwholesome or, more technically, wormy, filthy, and unfit for human consumption. Samples of such infested figs are shown in Plate I.

Figs as prepared and exposed for sale in the Northern United States are seldom injured to any great extent after arrival. It is doubtful if a second generation is ever produced, except in useless material. There is, however, always the possibility that the larvæ which are brought over here in consignments of dried figs, fruits, and other dry vegetable products may the following spring infest other food products, such as cereals, nuts, the seeds of cotton, flax, and others, which may be stored in the same buildings.

INSPECTION OF SMYRNA FIGS IN THE BUREAU OF ENTOMOLOGY.

During the year 1909, from September to January, many samples of figs—243 to be exact—were examined in the Bureau of Chemistry. Small lots from these samples, containing in most cases a few dead insects and in many cases excreta, were referred to the Bureau of Entomology, but with such small lots it was not possible to get any very valuable data from an entomological standpoint. During 1910, however, examination was made of a fair lot of samples, 30 in all, some purchased in open market, some furnished by Mr. E. G. Smyth, who sent or brought them direct from Smyrna, Asia Minor, including both sterilized and unsterilized figs, and a lot of "tapnets" and other bagged figs from New York, as also some samples furnished by the Dried Fruit Association of New York City, and one particularly bad sample furnished by the Bureau of Chemistry. These were all carefully examined by the writer from the standpoint of actual injury by insects, and the following is his report and summary. This in turn is followed by a report made by the Bureau of Chemistry on the seizures of figs made in 1909 in New York City (see p. 28).

CHTTN. No. 588.

Packages of figs sold in Washington, D. C., labeled "Smyrna layer figs, Turkey brand, packed in Turkey, prepared with glucose, packed and guaranteed by Van Dyke & Catrevas, New York and Smyrna, Turkey, under U. S. A. Serial No. 14902."

Sample 1, purchased of a Greek fruit dealer, December 21, 1910, on being opened showed that the figs had evidently been washed. Of the 11 figs, which were all of fair flavor except for slight acidity, there was evidence of attack by a single larva of the fig moth, its work being apparent on 3 figs. One parasitic cocoon and a trace of excreta were present on the 3 figs which were not quite perfect.

Sample 2, from same Greek, December 5, 1910, showed no evidence of insect attack, but one fig was considerably soured.

Sample 3, from same Greek, December 5, 1910, contained a single dead larva.

Samples 4, 5, 6, 7, 8, 9, and 10, the last three examined in February, 1911, were perfectly sound as regards the presence of either insects or evidence of their work.

CHTTN. NO. 1185. UNSTERILIZED SMYRNA FIGS.

Sample 11.—Sent by E. G. Smyth from Grand Hotel Huck, Smyrna (Asia Minor), labeled "Pulled figs, not sterilized, packed September 16, 1910." Packed tightly and carefully in a thick box 8½ inches long, 3½ inches wide, and 2 inches high. When received at Washington, D. C., November 5, 1910, one end of the packing box had become loose.

From the sides of this mass of figs, which came out entire, everything looked clean, but on removing and examining each individual fig—30 in all—every one contained more or less excreta, much of which, however, could be readily brushed off.

There was no evidence of living insects at this time or later, when examined March 8, 1911.

CHTTN. NO. 1186. SMYRNA FIGS STERILIZED BY DRY HEAT (233° F.).

Sample 12.—Grand Hotel Huck, Smyrna (Asia Minor), labeled "Figs sterilized in oven by dry heat, September 20, 1910; time 20 minutes; average temperature 112° C. (233.5° F.); shipped October 14 by E. G. Smyth;" received in the Bureau of Entomology, Washington, D. C., November 5.

The figs were all separated and showed the effects of sterilization by dry heat in their bleached color. A careful but not microscopic examination was made of every fig, 40 in all, with the result that on looking over all of them a second time only one fig was found to be in any way unfit for human consumption. This single fig showed a hole on the side through which a larva had escaped, and the usual amount of excreta for one larva was contained therein.

CHTTN. NO. 1195. LAYER FIGS SCALDED AT 212° F.

Sample 13.—Labeled by E. G. Smyth "Figs scalded in hot water at 100° C. (212° F.) for 16 seconds, water containing 2½ per cent salt and some glucose."

Careful examination in February, 1911, of this sample, which was packed under Mr. Smyth's direction, September 2, 1910, showed absolutely no signs of infestation by insects, but the figs were unpleasantly sticky and adhered to the box.

CHTTN. NO. 1187. UNSTERILIZED PULLED SMYRNA FIGS.

Sample 14.—Grand Hotel Huck, Smyrna (Asia Minor), labeled by E. G. Smyth "Pulled figs, not sterilized, packed September 16, 1910;" received in the Bureau of Entomology, Washington, D. C., November 5. Oblong box, identical with No. 1185, as tightly closed as possible, containing 30 figs.

On opening this box on day of receipt 4 nearly grown larvæ were seen resting on one side between the layers of figs. Further search in taking the figs from the box and transferring them to a rearing

jar showed the presence of 10 dead larvæ in all. A very large percentage of the figs was so much tainted with the excreta that they were not edible and would not pass an ordinary examination.

CHTTN. No. 1188. FIGS STERILIZED BY IMMERSION AT 215.5° F.

Sample 15.—Labeled by E. G. Smyth "Pulled figs, immersed 10 seconds in water at 102° C. (215.5° F.) before being packed." Water contained 2½ per cent salt. Shipped from Smyrna, Asia Minor, September 16, 1910; arrived at Bureau of Entomology November 5, 1910.

The immersion seems to have been somewhat unsatisfactory, judging by this lot, in that out of 30 figs in all, 24 would readily pass muster, while the other 6 were "wormy." Unfortunately for the success of this experiment, 2 larvæ were found, one living and one apparently dying. The figs did not present a good appearance when received, being extremely moist and sticky.

CHTTN. No. 1189. FIGS STERILIZED BY WATER, 215.5° F.

Sample 16.—Labeled by E. G Smyth "Pulled figs" immersed 10 seconds in water at 102° C .(215.5° F.) before being packed. The water contained 2½ per cent salt, evidently sea water. Shipped on Smyrna truck September 16, 1910; received at Washington, D. C., November 5, 1910.

The figs, though damp and moist, were practically uninfested. At one end a very slight indication of insect injury was observed. Number of figs 30; taste excellent, but stickiness rather undesirable. In this case, upon removing the cover the figs presented a beautiful appearance.

CHTTN. No. 1190. FIGS STERILIZED IN HOT WATER AT 212° F.

Sample 17.—A 5-pound lot of layer figs labeled "Figs scalded in hot water," at 100° C. (212° F.) for 10 seconds, water containing 2½ per cent salt, and some glucose, from Smyrna, Turkey in Asia, September 17, 1910; packed under observation of E. G. Smyth. Received December 17, and opened December 20, 1910, at Washington, D. C.

Careful examination of this lot of figs by the writer showed that about one dozen, chiefly from one end, had a more or less pronounced acid odor. In every case there was also more or less acid taste. Where the fig was dark from fungus infection the acid flavor was pronounced, especially to one who had eaten an entire fig. The writer and Mr. Smyth detected this more readily than several others. With the exception of the finding of a few badly spoiled figs, which might have been readily picked out by the consumer, and a single larva (which had very evidently crawled into a crack in the box), the process of sterilization was successful and had not caused souring. It had certainly entirely prevented infestation by the larvæ. This sample would pass as prime fruit.

CHTTN. No. 1191. LOCOUM FIGS.

Sample 18.—A package of "Locoum" figs in a wooden box seized by the Bureau of Chemistry on account of the presence of "worms," was received at the Bureau of Entomology February 1, 1911, and carefully examined for insect injury.

Of the 75 figs examined, 20 showed more or less insect injury, but no insects whatever were present. Of this number the majority, to the number of 16, showed injury more or less plainly on the outside, some containing worm holes penetrating to the interior, others simply small holes which did not penetrate and which contained only slight excreta on the interior. Four figs only showed decided evidences of excreta in the interior. The remainder were sound so far as insect attack was concerned, but it was noticeable that 6 of these figs were badly soured.

To summarize, out of the entire 75, 10 figs were not edible—4 on account of insect excreta in the interior, 6 on account of sourness—while the remainder were not sufficiently injured to be rejected by the average consumer. Nevertheless, since the top layer was worst affected, the box when first opened presented a bad appearance. As usual, injury was most pronounced at one end, at the end where examination began.

CHTTN. No. 1192. LOOSE FIGS STERILIZED IN STEAM CLOSET AT 239° F.

Sample 19.—A wooden box of loose figs sent by Mr. Smyth from Smyrna, October 6, 1910, sterilized in a steam closet at 115° C. (239° F.) for 10 minutes; examined in the Bureau of Entomology by the writer.

This package contained 75 figs, of which 59 were perfectly sound, showing no positive evidence of insect attack. One was sound but with slight excreta and with one dried pupal skin on the exterior; 11 were spoiled, mostly with excreta internally; 1 was spoiled with 1 dead and dry larva and excreta and another was spoiled with a wormhole and excreta internally; 2 otherwise badly spoiled figs had excreta internally.

CHTTN. No. 1193. DUPLICATE OF No. 1192, CONTAINING 60 FIGS; EXPOSURE 30 MINUTES.

Sample 20.—Of these 51 were sound, 6 showed excreta internally, while 3 were spoiled from other causes. The figs containing excreta in both lots were in most cases split, giving ready access to the insects.

INSPECTION OF SAMPLES OF FIGS FROM THE DRIED FRUIT ASSOCIATION.

CHTTN. No. 1194.

Sample 21.—In a lot of samples of figs labeled "rejected and ordered reexported or destroyed," submitted by Mr. L. B. Parsons, president of the Dried Fruit Association, New York City, and Mr. Davis, Bureau of Trade Relations, 507 Union Trust Building, and kindly furnished for examination to the writer in January, 1911, the following report is made:

Sample 22.—Labeled "C. A. A., 722 Laselle brand, fancy Locoum figs," packed in a box $7\frac{1}{2}$ by $8\frac{1}{2}$ inches and 2 inches deep. Five out of 25 of the figs of the upper layer, upon removal, showed slight evidence of excreta of the fig moth. A few particles, of course, could be seen on some of the other figs. No insects were found on this layer and no wormholes.

Sample 23.—Labeled "C. A., 36 Laselle brand, fancy Smyrna layer figs," showed on the upper layer 2 wormholes in one fig, 1 dead specimen of *Carpophilus hemipterus* L., and 1 living larva of *Silvanus surinamensis* L. No other infestation was apparent from this examination.

Both samples, judging from external layers, were otherwise in excellent condition.

Sample 24.—Labeled "London brand or extra choice natural fig for manufacturing." This contained evidences of attack by 3 larval fig moths.

Sample 25.—Labeled "Sterling brand or good average for manufacturing." This did not show evidence of insect attack by careful examination.

Sample 26—"*N. Y. 23,702.*"—A large box of figs bearing this number, submitted by the Bureau of Chemistry for examination, labeled "London layer figs, carefully selected," containing between 10 and 12 pounds, was received and examined February 13, 1911.

Without pulling all of the figs apart, a good estimate was given of their condition. There was external evidence of fig worms in the shape of large "wormholes," on 3 figs on the upper layer. At opposite ends on the lower layers injury was much more noticeable than on the upper layers—something unusual. At least 50 per cent of the figs contained more or less excreta, of which about 35 per cent contained a sufficient amount to cause their rejection by any fastidious would-be purchaser or consumer. Without opening all of the figs, there were estimated to be at least 30 larvæ or fig worms, all full grown and dead, with the exception of two which were living. The figs were, moreover, not as clean as desirable, containing small bits

of hair and of matting and some insect webbing. Some figs were also badly soured, some were lightly covered with dirt and mold, and altogether the boxful presented a filthy appearance.

CHTTN. NO. 1196. MIXED FIGS STERILIZED BY DRY HEAT AT 190.5° F.

Sample 27.—Labeled by E. G. Smyth "Figs sterilized in oven by dry heat September 21, 1910, subjected to 5 minutes average temperature 88° C. (190½° F.), Smyrna, Turkey in Asia." Received at Washington, D. C., November 5, 1910.

Examination showed absolute freedom from insects and even from excreta. Kept in nearly air-tight jars, the figs retained their flavor without acidity until March 8, 1911, when the record was closed. The flavor of these figs, although they were rather dry, was better than that of some of the best layer figs sterilized by hot water.

CHTTN. NO. 1197. LOCOUM FIGS STERILIZED BY DRY HEAT AT 225° F.

Sample 28.—Labeled "Grand Hotel Huck. Locoum figs sterilized in oven by dry heat, September 20, 1910; 15 minutes, average temperature 107° C. (225° F.), packed by E. G. Smyth," examined March 8, 1911; contents, 24 figs.

Six figs showed excreta mostly in the "eye" end and with some slight amount of loose excreta, which was removed almost immediately upon shaking. The remainder of the figs was sound, and although kept in a dry heated atmosphere they were of excellent flavor, although somewhat dry.

N. Y. 23782, 23139, 22758 AND 22760, PORTUGAL TAPNETS.

Samples Nos. 29, 30, 31.—From the Bureau of Chemistry were received the above samples of Portugal "tapnets" or bagged figs withheld because of infestation by what may be properly called the fig mite (*Carpoglyphus passularum* Hering). The species was identified by Mr. Nathan Banks, of this bureau, who stated that it is a common species found on dried fruit the world over, that it is not the cause of the souring of the figs, and in no way injurious to the consumer. There can be no doubt that this decision gives these forms of mites the same status as those found in other stored foods such as flour, meal, and other cereals and in old sugar and cheese. In fact, the latter commodity is seldom free from these microscopic creatures, which have never been held to be in any way injurious to human life. No less than 516 bags of such figs were seized and held in New York City, but were finally released.

SUMMARY.

Sample.	Lot number.	Number of insects dead.	Number of insects living.	Percentage of excreta.	Percentage of infestation.	Source of samples.
1	588	1	0	27	10	Layer figs purchased in open market.
2	588	0	0	0	0	Do.
3	588	1	0	0	10	Do.
4	588	0	0	0	0	Do.
5	588	0	0	0	0	Do.
6	588	0	0	0	0	Do.
7	588	0	0	0	0	Do.
8	588	0	0	0	0	Do.
9	588	0	0	0	0	Do.
10	588	0	0	0	0	Do.
11	1185	0	0	100	25	Unsterilized "pulled" figs.
12	1186	0	0	2.5	2.5	"Locoum;" sterilized by dry heat, 233.5° F.; 20 minutes.
13	1195	0	0	0	0	Sterilized by hot water, 212° F.; 10 seconds.
14	1187	10	0	75	25	Unsterilized Smyrna figs.
15	1188	2	0	20	....	Sterilized by immersion at 215.50° F.; 10 seconds.
16	1189	0	0	0	0	Sterilized as in No. 15.
17	1190	1	0	0	1–	"Locoum;" sterilized by immersion at 212° F.; 10 seconds.
18	1191	0	0	26	26	Condemned for "worminess."
19	1192	2	0	21	10	Sterilized at 239° F. steam; 10 minutes.
20	1193	0	0	10	5	Do.
21	1194	0	0	Slight.	0	Condemned by Bureau of Chemistry.
22	1194	1	1	0	0	Do.
23	1194	3	0	Slight.	5	Do.
24	1194	0	0	0	0	Do.
25	N. Y., 23, 702.	28	2	50	25	Do.
26	1196	0	0	0	0	Sterilized by dry heat; 190.5° F.; 5 minutes.
27	1197	0	0	25	(a)	Sterilized by dry heat; 225° F.; 15 minutes.
28	N. Y.,23, 782; 23, 139;22, 758; 22, 760.	(b)	(b)	....	(a)	Portugal tapnets withheld by Bureau of Chemistry.
29	....	(b)	(b)	25	(a)	Do.
30	....	(b)	(b)	25	(a)	Do.

a All edible. b Microscopic mites.

In the above summary it should be noted that the percentage of excreta is no indication of what may be considered the percentage of infestation, since the excreta become loose and adhere slightly to uninfested figs. It will be noted that samples 1 to 10, purchased in open market, were free from insect injury except in two cases.

In the case of sterilized figs there was, as a rule, a considerable difference from the unsterilized figs from the same source. It is obvious, as Mr. Smyth informs me, that the heat in many cases was not applied sufficiently high, and was not continued long enough to entirely penetrate such large masses as 5 or 6 pounds of layer figs. Of the 30 samples examined, Nos. 1 and 3, each containing 10 per cent of infestation, Nos. 11, 14, and 25, each containing 25 per cent of infestation, and No. 18, containing 26 per cent, not one could be pronounced inedible, and it will be noticed that Nos. 27 to 30, although containing a considerable percentage of excreta and microscopic mites, were also considered edible. No. 1185 would be pronounced unfit for human food on casual examination, but in reality,

when shaken and slightly brushed, these figs came out in first-class condition and were pronounced of exceptionally fine flavor.

In no case could it be positively said that the heating processes, whether dry, wet, or by steam methods, had caused souring, although one case of figs which had been sterilized was examined and some slight acidity noticed on the figs, probably existent before treatment by heat.

AVERAGE INFESTATION OF SMYRNA FIGS ENTERING THE PORT OF NEW YORK.

	Per cent.
Average of 4 samples arriving during September	24.05
Average of 54 samples arriving during October	25.14
Average of 115 samples arriving during November	27.36
Average of 51 samples arriving during December	30.99
Average of 19 samples arriving during January	38.17

The above averages include injury to figs attributed to the larvæ of *Ephestia cautella*, but more particularly to their excreta, and are taken from records carefully computed in 1909 and 1910 in the Bureau of Chemistry, and submitted by Dr. F. L. Dunlap. As previously stated, a total of 243 samples in all was examined in that bureau.

These figures show what had previously been deduced by the writer from experience with other related species, namely, that the early figs are least infested and that the latest figs introduced into this country from abroad are more infested than the earlier ones.

LIFE-HISTORY NOTES ON THE FIG MOTH.

The fig moth in America, so far as we can at present learn, is practically confined as a pest to rice, flour, and other mills, and to warehouses and storage rooms, and the notes which have been made in regard to its life history are solely from the standpoint of its life as an indoor pest. The results of experiments show very little difference between the life history of the fig moth and that of the Indian-meal moth—very similar species, nearly identical in size and habits.

OVIPOSITION.

All of the eggs that have come under observation were deposited singly and loosely, being readily detached by a slight touch.

Three females were selected for the determination of the number of eggs that might be laid. The first, although full-bodied, had evidently already begun egg-laying, since she yielded only 132 eggs by oviposition and dissection. The second deposited, in round numbers, 165 eggs and upon dissection yielded 115 more and contained

135 undeveloped eggs, a total of 415. The third, which was taken in copula at the time, laid by actual count 357 eggs, and 7 fully developed eggs were added by dissection, in all 364.

Eggs that were laid during the night of July 13 were found to have hatched on the morning of July 17, giving a period for the egg state of not more than 3½ days. The temperature of the room in which this experiment was conducted at this time ranged from 83° to 88° F., during the last night running down to 73° F.

THE TRANSFORMATION TO PUPA.

The larva or caterpiller, when it has attained maturity, has the same habits as those of *E. kuehniella* and *Plodia interpunctella*, of crawling about for a long time in search of a place for transformation to pupa. If anything it spins more web than even Plodia at this time.

Several full-grown caterpillers were isolated for observation of the period of pupation with the unlooked-for result that several individuals transformed to pupa during the daytime. One of these transformed at 1 p. m. and another at 4 p. m., July 13, a third at 8 a. m. the following day, and a fourth at 2 p m.

1. Pupated July 13, 4 p. m.; adult found July 22, 3 p. m.; 9 days.
2. Pupa found July 14, 8 a. m.; adult found July 22, 3 p. m.; 8+ days.
3. Pupated July 14, 8 a. m.; adult found July 22, 3 p. m.; 8+ days.
4. Pupated July 14, after 5 p. m.; adult found July 23, 9 a. m.; 8½ days.
5. Pupated July 15, about 5 a. m.; adult found July 24, 8.30 a. m.; 9 days.

The average temperature was about 83° F.

Other individuals that were under observation transformed as follows:

No. 6, in 16 days in early May; No. 7, in 24 days in October, cool weather; No. 8, in November, warmer weather, 19 days.

We thus have a pupal period of from about 8 days to 24 days.

July 14, at 8 a. m., a pupa was noticed in the act of shedding its larval skin. By a few peculiar movements the skin was worked farther and farther down until the abdomen was entirely exposed. The entire operation under favorable conditions would not consume more than about 3 or 4 minutes, judging from the rapidity with which the abdominal segments were freed.

THE LIFE CYCLE.

A number of moths was confined with flaxseed meal April 14 and the first adult was found to have emerged June 1, or in 48 days from the presumptive time of the deposition of the first eggs. A week elapsed before the appearance of another moth, when 8 issued.

Moths were reared from corn meal as follows: Parents confined in a jar June 23; larvæ began leaving the meal July 20; new brood began to issue July 29, or in 36 days from the time the eggs were sup-

posedly laid. The temperature during this period had been by no means as high as in the minimum-period experiments with *Plodia interpunctella*, but during the last 2 weeks the thermometer had registered above 80° F. most of the time, ranging from 73° to 89°, with an average of about 82° F.

From the foregoing it will be seen that the minimum period of the life cycle in midsummer in the Middle Atlantic region of the United States is about 5 weeks and the periods in late autumn and spring 7 weeks. The species hibernates in the larval and the moth states and does not breed out to any extent during the colder months, but occasionally adults emerge in superheated rooms.

The egg state, it has been shown, may last no longer than 3½ days, although in cool weather this period may be protracted into 2 weeks. Deducting the minimum periods of egg and pupa from the 36 days covered by the entire life cycle in midsummer we would have left 13 days for the midsummer larval period. From this may be deduced the following: Egg period, 3½ to 14 days; larval period, 13 to 30 days; pupal period, 8½ to 24 days; life cycle, 36 to 48 days.

The period of the hibernating larva has not been observed, but from analogy it appears certain that this period will vary greatly, some individuals remaining as larvæ months longer than others, irrespective of heat, moisture, or other conditions.

If the insect should happen to be breeding in a large mass of rice or corn meal, it could develop at the same rate as the Mediterranean flour moth, producing as many as six generations per annum, but in figs, walnuts, and similar material, where no great amount of artificial heat could be engendered, no more than four generations are probably produced in the average storehouse temperature. In our colder climates, where the species might be temporarily introduced, perhaps no more than three, or even two, generations would be produced.

NATURAL ENEMIES.

Two species of parasites which have received previous notice [13] have been observed by the writer, in addition to a mite, preying upon this moth. Undoubtedly it has many other natural enemies.

Hadrobracon hebetor Say.—On many occasions the little braconid *Hadrobracon hebetor* Say, which is now a well-known parasite of *Ephestia kuehniella* and *Plodia interpunctella*, was reared from the larvæ of this moth in walnuts, cacao beans, and other food materials. It was found in abundance at Smyrna attacking its host in figs. This species is illustrated in figure 3.

Omorga frumentaria Rond. (fig. 4.), also a parasite of grain and meal-feeding moths, was reared at this office from *E. cautella*. In one instance where the parasite was found in large numbers in a jar

in which its host was breeding, the eggs of the parasite must have been thrust through the cloth covering of the jar, which contained only fresh material, and there had been no exposure of its contents and no other manner for the parasites to have obtained access to this jar. Particulars in regard to this are furnished in an early publication of this bureau.[a]

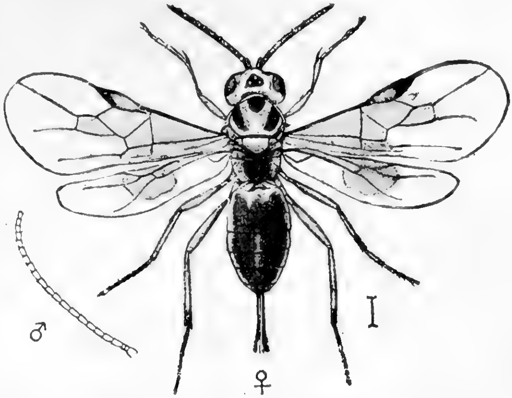


FIG. 3.—*Hadrobracon hebetor*, a parasite of the fig moth: Adult female; antenna of male at left. Greatly enlarged. (Author's illustration.)

Pediculoides ventricosus Newp.—The third count of eggs laid by this moth, related on a preceding page, was productive of an unexpected result in establishing the mite *Pediculoides ventricosus* as an egg parasite. In a glass tube in which a copulating pair of the moths

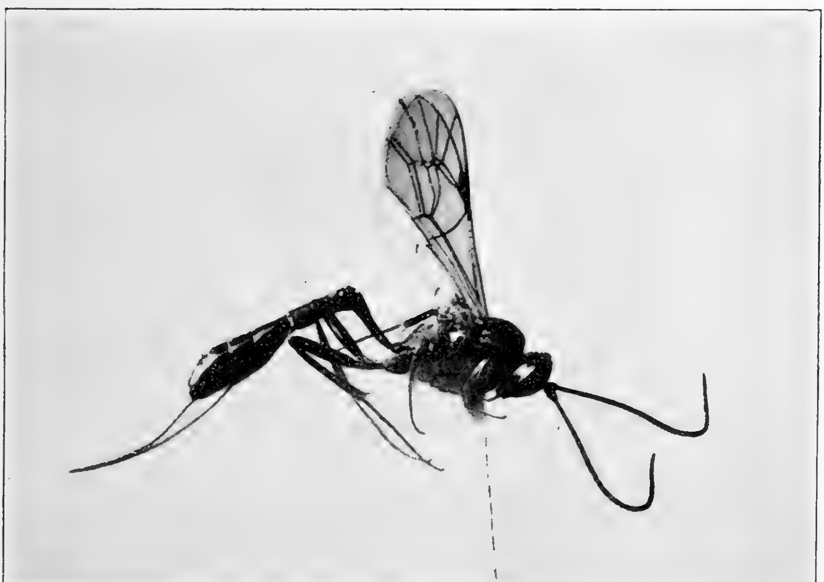


FIG. 4.—*Omorga frumentaria*, a parasite of the fig moth. Lateral view. Greatly enlarged. (Original.)

was confined, about a score of mites of this species was found, some attacking and sucking out the contents of the eggs, while numer-

[a] Bul. 8, n. s., Bureau of Entomology, U. S. Dept. Agriculture, p. 41.

ous moth eggshells and the full, rounded abdomens of all but one or two of the mites attested to their having made similar meals. Their bodies were almost identical in size with the eggs, from which they were only distinguished with a lens, and it is fairly certain that they were the progeny of a single adult that might have become attached to one or the other of the parent moths.

METHODS OF CONTROL.

The methods for controlling the fig moth in its occurrence in flour mills are the same as advised for the eradication of the Mediterranean flour moth, in which case we depend chiefly upon hydrocyanic-acid gas. In the case of smaller inclosures, where bisulphid of carbon is generally preferred, this can be used more readily and with about the same effect.

Preliminary work has been done in the fumigation of rice mills infested by the fig moth and other species of insects, which indicates that, owing to the more open structures where rice milling is in operation and the difficulty of closing the many apertures in these mills, fumigation is not always practicable.

A small series of useful experiments was recently conducted by Mr. D. K. McMillan and by Mr. M. M. High, while working under the writer's direction in Texas in the fumigation of rice mills.

Both hydrocyanic-acid gas and bisulphid of carbon were successfully employed after the mills or portions of them had been made as tight as could be done economically.

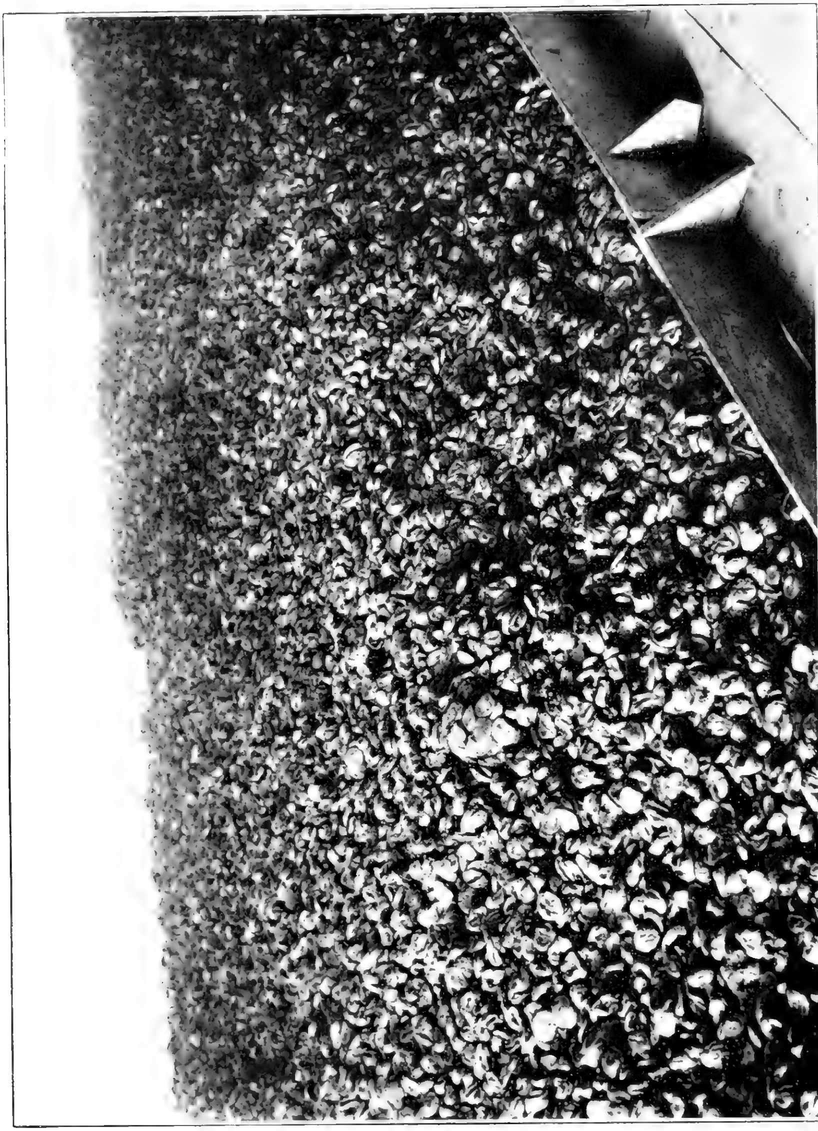
Carbon bisulphid was used upon adults and larvæ, chiefly of beetles, in rice bran and other materials in tight flour barrels at the rate of 5 pounds to 1,000 cubic feet of air space and 10 pounds to 1,000 cubic feet, each for 12 hours and 24 hours. Adults were killed in all four cases and larvæ in all cases except with the 5 pounds for 12 hours, where some insects crawled up to the top of the barrel and did not get the effect of the gas.

In fumigating mills at Fort Worth and at Dallas, Tex., *Ephestia cautella* occurred in each mill in small numbers.

Cyanid of potash was used in three mills at the rate of 10 ounces to 1,000 cubic feet as the weakest dosage. Adults were all killed and no living larvæ were to be found after careful search and thorough airing of material.

In a series of experiments in a fumigating room at Beaumont, Tex., the species occurred in sacks of rice bran and polished rice. With the dosage of 10 ounces of cyanid of soda to 1,000 cubic feet for 12 hours, adults and larvæ of this species were all killed and consequently with heavier dosages for a longer time.

The effect of cyanid upon the eggs could not be observed, owing to inability to find them.



PILE OF FIGS IN FIG DEPOT—ONE OF THE PRIMARY PLACES OF INFESTATION. (ORIGINAL.)

Directions for fumigating mills and other structures by the hydrocyanic-acid gas process are furnished in Circular No. 112 of the Bureau of Entomology, and instructions for the use of bisulphid of carbon as a fumigant are discussed in Farmers' Bulletin No. 145, both of which publications may be obtained on application to the Secretary of Agriculture.

While fumigation is not at present practicable in most of the "khans" of the fig-packing companies of Smyrna because of the impossibility of making them sufficiently tight for the purpose, there are still chances of ultimate success. For the perfect success of any form of fumigation of insects affecting stored products it is highly desirable that the buildings or other inclosures in which the material is stored be made perfectly air-tight. Under these conditions the minimum amount of bisulphid of carbon or other fumigant and the minimum exposure can be employed. Whatever fumigant is used, at least 24 hours' exposure is desirable, and in many cases 48 hours—particularly if the buildings are not quite air-tight—are necessary, especially in comparatively low temperatures. In preparing this paper for publication it occurred to the writer that perhaps, everything considered, the most simple means of fumigating, that is, with bisulphid of carbon, would be the best for treatment of fig-packing houses. The writer has exchanged opinions on this topic with three fig experts and as many entomologists, and they have all agreed that this should be a good method if employed by erecting special fumigating houses, to be made air-tight and placed at some distance, say, about 25 yards, from the main building. While it would be better to have these buildings constructed of concrete, they can be built of wood and lined both inside and out with stucco or cement. This would not only render them more nearly air-tight, but would, moreover, serve as an additional precaution against fire. It remains to be determined what amount of bisulphid of carbon would be the best for use in such buildings.

Efforts have been made to free the figs of "worms" by vacuum treatment, but with indifferent success. With layer figs in boxes it is not practicable.

We must, therefore, look for preventives and other more or less direct remedies. From the report on this insect made by Mr. E. G. Smyth, entomological assistant, engaged in stored-product insect investigations from August to November, 1910, in Smyrna, Turkey in Asia, the followng lines of treatment are suggested:

PREVENTIVES.

The principal time of infestation is while the figs are on the ground drying in the sun, and later, when piled in the fig depots (Pl. II), before shipment to Smyrna from the interior, where the figs are

chiefly grown; but the original infestation is due to carelessness in permitting the unmarketable figs of the June crop to remain in the field and serve as a breeding place for the pest. If this source of infestation could be removed by the complete destruction of the June crop, it seems probable, from present knowledge of the insect's habits, that in the course of time injury by this moth could be reduced to a minimum, since other opportunities for infestation are slight and not worthy of consideration. The framing of a regulation for the destruction of the June fig crop is advisable, and its enforcement should be attempted. In case of failure in the enforcement of such a regulation, the next step would be to protect the figs at night, while they are drying on the frames called "serghi," with a covering of cloth of a mesh sufficiently fine or of proper texture to prevent oviposition. This should be followed by the exclusion of the moths from the fig depots, where figs are heaped in piles, as shown in Plate II, by closely screening the doors, windows, and other openings, so as to make them moth-proof. After the figs are placed in goat's-hair bags infestation from this point onward practically ceases, so far as egg laying is concerned.

The pernicious practice of some growers and middlemen, of holding figs in the interior, could be stopped by stringent action by those most interested, and thus another cause of infestation would be eliminated.

HEAT AS A REMEDY.

The impracticability of other direct methods of treatment led to experiment with the simplest means of destruction of insects in stored products, viz. the application of heat, by steam, hot water, and hot air. Preliminary experiments were made along this line and should be continued by the packers to ascertain the length of time in different temperatures, pressures, and exposures to produce the best effect.

Figs scalded in early September had not shown indication of souring to late in December, while if exposed too long at the boiling point figs, it is claimed, acidify. It would seem that boiling is one of the best direct remedies that could be used, since a large proportion of the packers boil the figs intended for their own consumption, thus destroying between 80 and 100 per cent of the "worms" without additional expense in manipulation. By the use of dry heat the loss of time incident to the employment of the wet method, for drying after treatment, is eliminated, and there is less tendency to souring. Furthermore, the color, texture, and appearance are less affected when dry heat is employed. Already an experimental plant for the application of dry heat, called "sterilization," has been installed in a large "khan" of Smyrna, and admirable success has been obtained in the destruction of the fig "worms." The dry process, however, possesses

a disadvantage in that it does not remove filth and possible germs on the figs as in the case of boiling.

Progressive packers are willing to install a system of sterilization, providing that such be ordered by the Turkish Government and imposed equally upon all packers.

The value of the insect enemies of the fig moth as a factor in the control of the insect in figs imported from Smyrna is doubtful, since, although as many as 50 per cent of the larvæ may be parasitized, this does not prevent the larvæ from working in the figs until maturity.

METHODS OF PACKING FIGS AS A PROTECTION AGAINST INSECT ATTACK.

The following notes have been made in the course of the examination, during the winter of 1910–11, of figs packed according to different processes.

All in all, the figs purchased in the open market, packed in small boxes, were less infested than those packed in the large 5-crown or 6-crown boxes shipped from Smyrna direct. The worst-infested figs examined were the string figs, which are, moreover, very dry and inferior in appearance. (See Plate III.) They make particularly easy the entrance of insects from the time they are shipped until the time they are purchased by the consumer, especially when kept in a warm temperature, as is frequently the case. After a while they lose much of the characteristic fig flavor.

The figs packed in layers (Pl. III) and sterilized by immersion in hot water, especially if they are submitted to a temperature of 100° C. or a little above, equivalent to 212° F., for a sufficient length of time to kill all the insects, become sticky and adhere so tightly in some cases that it is with difficulty that they can be removed from the boxes; and, moreover, the individual figs become agglutinated, so that in separating them they tear in the middle and do not separate properly.

The "Locoum" and pulled figs, everything considered, especially where subjected to dry heat, are not, as a rule, quite so much subject to damage as are the layer figs, and, moreover, keep their flavor decidedly better.

Samples of the best layer figs which had been treated by hot water were tested in comparison with "Locoum" figs of apparently not so good quality, and out of 14 persons who tested these for flavor 13 were decidedly in favor of the "Locoum" and pulled figs as possessing the best flavor. Only one person was undecided. Enough glucose is used in the layer figs which were treated with hot water to impart to these a somewhat sickeningly sweet taste. A little more glucose would give them the flavor of a confection rather than that of a fruit.

EXPERIMENTS WITH FUMIGANTS AT A HIGH TEMPERATURE.

[By F. H. CHITTENDEN and THOS. H. JONES.]

On May 18, 1911, the first good opportunity to test one of the fumigating gases against "worms" in figs was afforded. The desire was to have a high temperature, similar to that of Smyrna, and to make a test to determine if the insects could be destroyed at a profit in a short exposure. These experiments were conducted at Washington, D. C.

BISULPHID OF CARBON.

Since the majority of the fig-moth larvæ were dead and had been replaced in many instances by the Indian-meal moth (*Plodia interpunctella* Hübn.) during spring, figs infested by this latter species were used. The bisulphid of carbon was used at the rate of 1½ pounds to 1,000 cubic feet of air space, and the figs were placed in a specially prepared and very nearly air-tight fumigating box at 4.30 p. m. At this time the temperature was 90° F. When removed 24 hours later the temperature was exactly 100° F. The mean temperature was estimated at 96° F.

The figs were very thoroughly infested with the Indian-meal moth, there being an abundance of moths and larvæ. All were dead when examined on the morning of May 20. It is therefore safe to say that the fig moth can be destroyed in figs in an inclosure made sufficiently air tight, in a temperature between 90° and 100° F., which is apt to be encountered at Smyrna, and in a building especially constructed for this purpose, using 1½ pounds of bisulphid of carbon to 1,000 cubic feet of air space. There is no necessity for a longer exposure if the building is nearly air-tight, as in this case. The odor of bisulphid of carbon was quite perceptible when the insects were removed from the fumigatorium and was even perceptible in another room, to which the insects were removed, when opened the next morning. Up to June 3 no evidence of eggs hatching could be observed. The mass of figs fumigated was very carefully examined and no trace of young larvæ or eggs could be found. Eggshells, however, were seen and one nearly mature larva was still living, being incased in an unusually strong, somewhat leathery cocoon, placed tightly between two figs. With the amount of figs used in the experiment, this might be considered a perfect fumigation, since a single moth could not procreate and reproduce its kind.

It should be said that the Indian-meal moth (*Plodia interpunctella* Hübn.) is of about the same size as the fig moth in all its stages.[a] Therefore there would be practically no difference in the resistant power of the two species against any gas which might be employed.

[a] It has already been recorded that these two species have been observed *in coitu*, but the resulting eggs were not fertile.

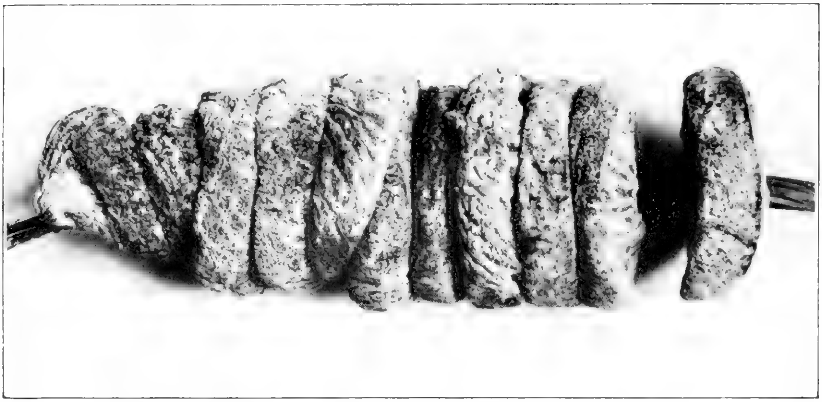


FIG. 1.—FIGS PACKED BY STRING METHOD. REDUCED. (ORIGINAL.)

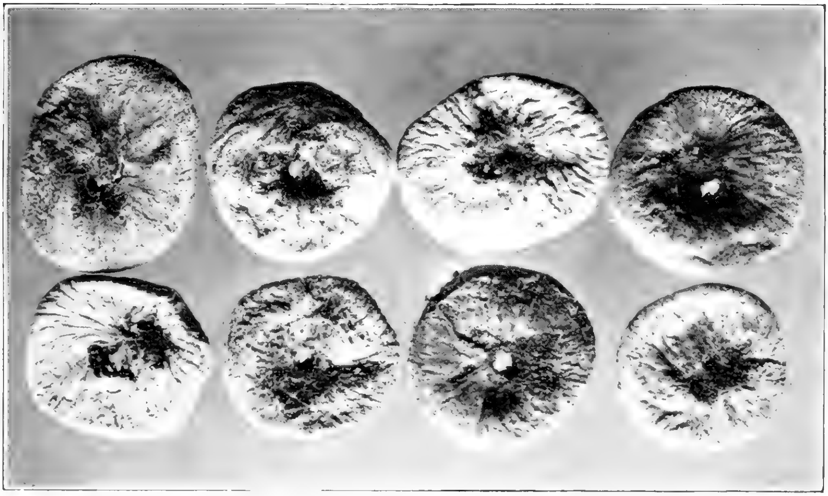


FIG. 2.—SOME OF SAME FIGS AS SHOWN ABOVE, TO ILLUSTRATE LARVAL INFESTATION. REDUCED. (ORIGINAL.)

PACKAGE OF SMYRNA FIGS PACKED IN TURKEY FOR AMERICAN TRADE, ACCORDING TO LAYER METHOD. (ORIGINAL.)

The fig moths, as has been stated in other portions of this bulletin, usually soon die out in America and are replaced in this country in the same material by the Indian-meal moth, which is more hardy and more nearly omnivorous.

HYDROCYANIC-ACID GAS.

Experiment No. 1.—June 23, at 4.05 p m., in a recorded temperature of 94° an experiment was made in the hope that the temperature would continue or increase, as frequently happens in the District of Columbia. In this experiment, which was conducted under the writers' personal supervision, Messrs. Duckett and O'Neill assisted. June 24, Mr. O'Neill made count of the insects after removal from the fumigator at 4.05 p. m. It will be seen that this was the usual 24-hour exposure. The proportions used were 6 ounces of sodium cyanid and 6 ounces of sulphuric acid to 1,000 cubic feet of air space. Owing to atmospheric conditions probably the exact temperatures and other conditions were not recorded, but the minimum was not lower than 80°, which would give a mean temperature of about 85°F. This experiment was conducted chiefly for the purpose of testing the results on the Indian-meal moth (*Plodia interpunctella*). Large numbers of these were in dried figs, packed as closely as possible. The result was that only 60 per cent were killed, showing that a relatively heavier dosage is necessary to kill this insect than is the case with bisulphid of carbon.[a]

Experiment No. 2.—Owing to the failure of the first hydrocyanic-acid gas fumigation experiment, undertaken June 23, a second experiment was found necessary. This was started at 3.45 p. m., June 27, and the same formula, 10 ounces of potassium cyanid and 10 ounces of sulphuric acid to 1,000 cubic feet, was used. The temperature during this period was 92° at the beginning, the lowest temperature recorded, between 6 and 8, being 80°, when the fumigation was completed. The mean temperature was about 85° F. Exposure was as before, exactly 24 hours being the time. The Indian-meal moth larvæ and adults in figs were all killed. The same was true of their occurrence in meal. The granary weevil was completely destroyed, and the same is also true of the lesser grain borer and the saw-toothed grain beetle. Only one species of insect survived: Four living adults of the *Tribolium confusum*, the confused flour beetle, in meal were not killed. It would be difficult to determine the percentage in this case.[b]

[a] Of other insects treated at this time, specimens of the lesser grain borer (*Rhizopertha dominica* Fab.) were all destroyed, furnishing additional testimony of the weak resistant power of this species to both gases.

[b] The larvæ and moths of the Mediterranean flour moth (*Ephestia kuehniella* Zell.) were also all killed, and the same was the case with the Indian-meal moth in meal. The saw-toothed grain beetles (*Silvanus surinamensis* L.) were all destroyed, but of the granary weevil (*Calandra granaria* L.) only 82.5 per cent were destroyed. In the case of the rust-red flour beetle (*Tribolium navale* Fab.) three larvæ were living. The four-spotted bean weevil (*Bruchus* [*Pachymerus*] *quadrimaculatus* Fab.) was destroyed.

SUMMARY.

To summarize the measures for the eradication of the fig moth in imported figs we may reduce them to the following methods of prevention and destruction:

(1) Prompt disposal or destruction of the useless June fig crop.

(2) Covering the figs at night while on the "serghi."

(3) Closely screening the fig "depots" in the interior.

(4) Prompt delivery of the figs to the "khans" after gathering.

(5) Destruction of the "worms" in the "khans" by "sterilization," i. e., by hot water, dry heat, or steam.

(6) Fumigation by means of carbon bisulphid in special fumigation structures, made as nearly gas-tight as possible.

(7) Fumigation by means of hydrocyanic-acid gas.

(8) Construction of the "khans" in the future so that they can be made gas-tight for the purpose of fumigating.

(9) Enactment of special regulations or legislation to secure the enforcement of the suggestions made.

(10) Clean methods of handling and storing at all times and in all places.

BIBLIOGRAPHICAL LIST.

1. Walker, Francis.—List of the specimens of lepidopterous insects in the collection of the British Museum, pt. 27, 1863.
   Original description as *Pempelia cautella,* from Ceylon.
2. Zeller, P. C.—Stettiner Entomologische Zeitung, p. 384, 1867.
   Description as *Ephestia cahiritella* from two examples from Cairo, Egypt.
3. Barrett, C. G.—Entomologist's Monthly Magazine, vol. 11, p. 271, May, 1875.
   Redescribed as new under the name of *Ephestia passulella;* in dried "currants."
4. Buckler, Wm.—Entomologist's Monthly Magazine, vol. 19, pp. 104–106, October, 1882.
   Reared from eggs placed on "locust bean of commerce." Description of eggs, larva, and pupa.
5. Porritt, G. T.—Entomologist's Monthly Magazine, vol. 19, p. 142, November, 1882.
   Feeding on dried figs; said to be partially double brooded.
6. Porritt, G. T.—Entomologist's Monthly Magazine, vol. 20, p. 41, July, 1883.
   Larvæ stated to winter in cocoons and transform to pupæ in spring.
7. Atmore, Edw. A.—Entomologist's Monthly Magazine, vol. 20, pp. 258, 259, April, 1884.
   Introduction at King's Lynn, England, in cottonseed-oil cake from Galveston, Tex.
8. Ragonot, E. L.—Entomologist's Monthly Magazine, vol. 22, p. 24, July, 1885.
   Short note on distribution and hibernation.
9. South, R.—The Entomologist, vol. 23, pp. 304–305, October, 1890.
   Description (from Barrett); distribution; bibliography; larva "feeding on cottonseed-oil cake."
10. Pearce, W. T.—The Entomologist, vol. 24, p. 18, January, 1891.
    Brief mention of the occurrence of the larva in dried currants and of the presence of a small black ichneumon parasite.
11. Riley, C. V.—Insect Life, vol. 6, p. 221, February 28, 1894.
    Mentioned as *Ephestia* sp., found breeding in cacao beans at the World's Columbian Exposition in 1893.
12. Meyrick, Edw.—Handbook of British Lepidoptera, p. 373. London and New York, 1895.
    Description, distribution, and brief notes.
13. Chittenden, F. H.—Bul. 8, n. s., Division of Entomology, U. S. Department of Agriculture, pp. 7–9, fig. 1, 1897.
    Identification of this species from both North and South America; food habits; brief descriptions of larva and moth; original figures of eggs, larva, and moth.
14. Chittenden, F. H.—Bul. 8, n. s., Division of Entomology, U. S. Department of Agriculture, pp. 39–43, fig. 10, 1897.
    Record of the rearing of the parasites *Hadrobracon hebetor* and *Omorga frumentaria* from this species, with illustration of former.
15. Holland, W. J.—The Moth Book, p. 414, fig. New York, 1903.
    A one-page account, including remarks on inspection and quarantine for preventing the introduction of foreign insect pests.

16. LEFROY, H. M.—Indian Insect Pests, p. 256. Calcutta, 1906.

Common in India in flour and meal. Brief mention as *E. cahiritella.*

17. CHITTENDEN, F. H.—An insect likely to be mistaken for the flour moth. The American Miller, July 1, 1909, p. 545.

A short popular article, with illustration.

18. LEFROY, H. M., and HOWLETT, F. M.—Indian Insect Life, pp. 512, 513, fig. 340, 1909.

Feeds in rice and wheat flour in India and has been reared from tamarind seeds. Moth, larva, pupa, and work figured. Short note.

REPORT ON THE FIG MOTH IN SMYRNA.

By E. G. Smyth, *Entomological Assistant.*

In accordance with orders received from the Secretary of Agriculture, contained in a letter of authority dated July 1, 1910, and under specific instructions from Dr. F. H. Chittenden, contained in a letter of June 30, the writer sailed from New York on July 9 for Smyrna, Turkey in Asia, to investigate the problem of eliminating the fig moth (*Ephestia cautella* Walk.) and other insects injurious to dried figs.

SOURCES OF INFESTATION.

As in the solution of all similar problems of how to avoid injury from insect attack, before definite remedies could be prescribed it was necessary to determine the exact source of infestation. There are seven distinct periods in the preparation of Smyrna figs for market, before their receipt at New York, when infestation by moths is possible: (1) While the fruit is on the tree; (2) while drying on the ground; (3) in the fig "depots" of interior Asia Minor; (4) in the freight cars en route to Smyrna; (5) in the bazaars in Smyrna; (6) in the packing houses or "khans"[a] of Smyrna; and (7) in the steamers during shipment to America. All previously noted habits of the same moth in this country, where it occurs only in buildings or places where dried fruits or food materials are stored, pointed to the packing houses as the most probable source of infestation, it being a matter of common knowledge that in them conditions of uncleanliness are so bad that the moths, if once established, would breed generation after generation unmolested.

When the writer reached Smyrna, August 5, it was found that the fig export season had scarcely begun and figs were not yet arriving from the villages, so the interior of Asia Minor was visited Half of the month of August was spent in the Meander Valley (Pl. V, fig. 2), which furnishes about 90 per cent of the dried figs of Smyrna, and in immediate proximity to the trees, where every condition surrounding the maturing and dropping of the fruit could be noted.

[a] A Turkish and Syrian word—a caravansary or unfurnished inn; used in Smyrna to designate a packing house, because caravansaries are often used for fig packing.

OCCURRENCE OF LARVÆ IN THE ORCHARD.

If the larvæ, or "worms," come from the orchard, as held by the packers in Smyrna, and are in the figs when gathered, the same degree of infestation should be found on the ripening fruit on the tree as in the dried fruit in the market, which is seldom less than 15 per cent and often more than 50 per cent. But this is not the case. On rare occasions only were larvæ found in the ripe fruit on the tree.

In an orchard at Kara Bounar, August 18, many figs were picked from the trees and broken open, and a few found to contain young larvæ. Figs were ripening in numbers and shriveling on the trees, and some had dropped and been gathered and spread on "serghi"[a] at one side of the orchard to dry. A small percentage of these was also found infested. The larvæ were quite young, most of them less than two weeks old. Their presence was usually indicated by a silk webbing at the eye of the fig. In no case was the skin of the fig injured by the larva, nor was there other evidence of its presence within the fig.

In an orchard at Nazli many figs were broken open from the trees, but very few were found wormy. Those placed in jars, however, later turned out to be often quite wormy, as though eggs or very young larvæ had been present in them when they were picked. Larvæ found were of the usual pink color, and occurred, as a rule, one, and very seldom more than two, in a fig.

A smaller larva, the young of a nitidulid beetle, *Carpophilus hemipterus* L., sometimes occurred in small colonies of from 3 to 7 individuals at the open or eye end of figs on the trees or drying on the "serghi." These occurred usually in split or injured figs, and their presence never accompanied that of Ephestia larvæ in a fig.

Repeated attempts to find larvæ in figs on the trees in the large orchards at Tchifte Kaive were unsuccessful. The conclusion was that, while figs are sometimes attacked by the larvæ of the fig moth before they fall from the tree, it is the exception rather than the rule. The percentage of figs thus attacked is very small, the larger part of the infestation taking place later, while the figs are drying on the "serghi" or are piled in the fig depots.

EGGS ON FIGS ON THE TREES.

It was evident that the "worms" were not present in any number in the figs when they dropped from the trees. But as they were known to appear in the figs a week or two after their dropping, and to be present in numbers when the figs arrived in Smyrna from the

[a] Beds of reeds or other suitable plants laid upon the ground to protect figs from contact with the soil while drying.

FIG. 1.—EXTENSIVE FIG ORCHARDS IN VALLEY OF CAYSTRUS RIVER, ASIA MINOR. THE FIG MOTH IS ABUNDANT OVER THIS AREA. (ORIGINAL.)

FIG. 2.—TYPICAL SMYRNA FIG ORCHARD IN MEANDER VALLEY, ASIA MINOR, WHENCE COME THE BEST FIGS FOR EXPORT. THIS IS THE REAL HOME OF THE FIG MOTH. (ORIGINAL.)

interior, there seemed a possibility that the eggs were laid before the figs dropped from the trees. To determine if this were the case, hundreds of ripe or ripening figs on the trees were examined, but no eggs were found.

The first search for eggs in an orchard was made at Nazli, Asia Minor, on August 8. The fruit was just ripening and none had begun to shrivel or dry. The figs were closely examined, but no sign of Ephestia eggs was found. Ten days later a similar search for the eggs was made in an orchard at Kara Bounar, and, although the figs were much riper than previously and many were shriveling and dropping to the ground, the examination was fruitless of results. Both the outside of the skin and the interior of the eye of many figs were examined, but nothing having the appearance of fig-moth eggs was discovered. On the following day at Nazli figs were again examined in the orchard where observations were made on August 8. Still no eggs were revealed, even by the use of strong hand lenses.

Many attempts were made to find eggs on figs on the trees in an orchard at Tchifte Kaive, between August 21 and 26. A great many figs were cut open and the scales about the eye examined one by one, but no eggs were revealed. Several times, while examining figs, small, white, globular objects were found adhering to the skin. These, superficially, resembled the eggs of Ephestia, but when put under a good lens proved to be secretions of honey from the substance of the fig that had hardened on the outside.

MOTHS IN THE ORCHARD.

While search was being made for eggs in the orchard at Nazli a careful watch was kept for adults. The bark of trees was inspected, and débris and trash piles about the orchard were disturbed with a hope of arousing the moths. At Kara Bounar, August 18, reeds upon which the figs were drying were fruitlessly turned over in search of moths. The same was done on a later visit to Nazli, and vegetation in a vineyard closely adjoining a fig orchard was well shaken, but no moths were aroused.

When it became too dark to see, trees were examined by use of electric bull's-eye lamps. Chrysopid adults were thus revealed in numbers, flying about the foliage, and had the fig moths been present they would without doubt have been revealed by the light.

All efforts to locate moths about the trees, either in daylight or by the use of bull's-eye lamps, having failed, it was decided to climb a fig tree with an ordinary lantern and lie in wait for the appearance of the moths among the branches or foliage. This was done on August 25 in an orchard at Tchifte Kaive. In an hour's vigilance two moths were attracted to the light and a third seen flying among the foliage. Such a scarcity of moths could not account for the

wholesale infestation of dried figs, even in the event that the eggs had escaped detection. The only possible conclusion was that less than 10 per cent, and probably less than 5 per cent, of infestation of dried figs originates while the fruit is on the tree.

OVIPOSITION ON FIGS DRYING ON THE "SERGHI."

The first fig-moth adults seen in the interior of Asia Minor were at Nazli on August 19. A careful search had been made for them by day and in the early evening throughout the orchard with no success. About 7 o'clock, while watching the "serghi" (see Pl. VI, figs. 1, 2), a few moths were noticed fluttering over the drying figs. They increased in abundance, and by 7.30 p. m. were hovering over the beds of figs by dozens. It was impossible to determine from what source they came. They showed a particular fondness for crawling down among the reeds beneath, as though to reach the figs from the underside. They were evidently all of one species, *Ephestia cautella*, although they varied somewhat in size.

Moths were observed the following evening in another orchard where the figs were laid on the bare ground to dry, in place of upon beds of reeds. It was expected that the moths would prove less abundant in this case, there being no reeds present or other shelter in which they could hide by day. The lack of shelter, however, made little difference, for at dark they began to gather over the figs as on the preceding night, and quite as abundantly. A few were noticed as they approached the figs, flying close to the ground. Evidently the moths have no particular hiding place in which to pass the day, but simply secrete themselves about rubbish or foliage near the ground.

Observations of the moths ovipositing on figs on the "serghi" were made during a week's stay, August 21 to 27, at Tchifte Kaive, Asia Minor. The "serghi" used in this orchard were sufficient in area to accommodate the drying of large quantities of figs. They were composed of reeds taken from near the Meander stream and laid in long rows, 3 feet wide and half as far apart. (See Pl. VII, figs. 1, 2.) Observations were easily made along any of these beds from the alleyways between. As observed on previous occasions, the moths began to appear at about 7 o'clock and increased in abundance up to 8 or 8.30 p. m. As late at 10.30 p. m. they were found still active, and doubtless continued ovipositing until well toward morning. Lanterns were employed to observe the moths, which seemed unusually abundant at this place. Occasional moths were attracted to the lanterns, but usually they avoided the light. They were quick in their movements and hard to capture.

No individual was seen depositing eggs, for upon alighting the moth invariably crawled quickly to the underside of the fig, and if

FIG. 1.—THE CRUDE FORM OF "SERGHI" EMPLOYED IN MOST ORCHARDS FOR DRYING FIGS. FRUIT IS EXPOSED TO THE SUN FROM 2 TO 5 DAYS. (ORIGINAL.)

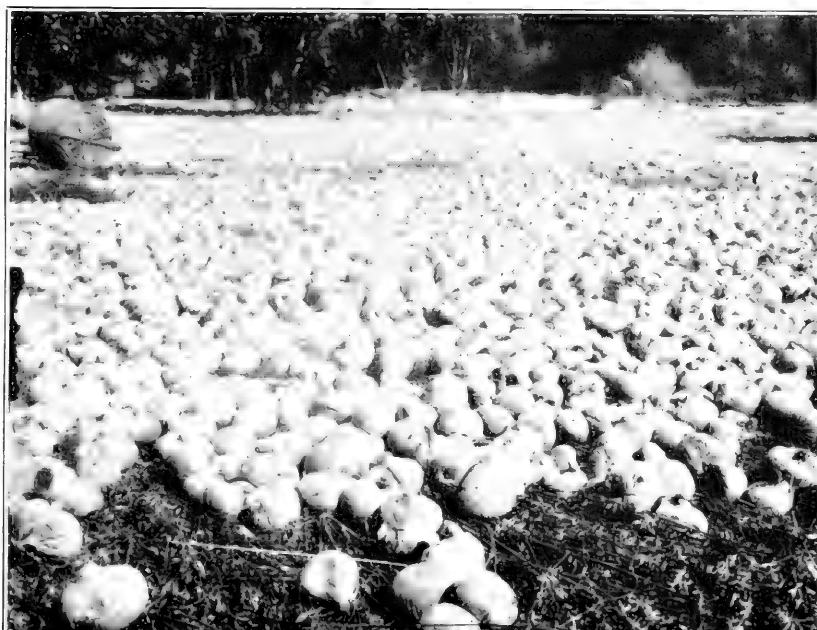


FIG. 2.—NEAR VIEW OF FIGS DRYING ON THE "SERGHI," NAZLI, ASIA MINOR, AUGUST 19, 1910. THIRTY-FIVE PER CENT OF THE FIGS BECOME INFESTED ON THE "SERGHI." (ORIGINAL.)

FIG. 1.—"SERGHI" OF REEDS LAID IN LONG ROWS, USED IN LARGE ORCHARDS. OVER THESE THE MOTHS CONGREGATE BY THOUSANDS AT NIGHT. (ORIGINAL.)

FIG. 2.—URUK GIRLS SPREADING FIGS ON "SERGHI" TO DRY. THE REEDS EMPLOYED ARE SPARTA SPARTIFOLIUM FROM THE MEANDER RIVER. TCHIFTE KAIVE, ASIA MINOR. (ORIGINAL.)

disturbed would take wing. The moths varied greatly in size, some having twice the wing expanse of others. The smaller individuals seemed to predominate. The small ones were less distinctly marked than the larger ones, although all were of one species.

A few moths, after being left a short time in a cyanid bottle and partially stupefied, were taken out and put into glass jars with figs. They soon revived, and by morning each individual so confined had laid a large number of eggs. The eggs were laid indifferently on the skin of the fig or on the sides of the jars, and many had dropped to the bottom of the jars. Eggs were usually deposited in the creases or furrows in the skin of the fig or on wounds or injured parts where the larvæ would find little difficulty in entering the fruit. They were never seen to be deposited within the eye or aperture of the fig.

PERCENTAGE OF INFESTATION ON THE "SERGHI."

The figs are gathered night and morning as they drop from the trees, and the large number of moths attracted to the "serghi" may be explained by the absence of figs on the ground in the orchard, as well as by the strong fragrance emitted by so many figs piled together. Figs remain from two to five days on the ground drying, fully exposed to the sun. No precaution is taken to cover or protect them at night, so that they are exposed as many nights to the ravages of the moths.

A count was made at Tchifte Kaive, August 26, to determine the percentage of figs that become infested on the "serghi." Figs that had laid exposed for one night, two nights, and three nights were examined, 200 being counted from each lot. The number of eggs on each fig was not recorded, the presence of a single egg causing a fig to be considered as infested. The following degrees of infestation were found:

Exposure.	Number of figs.	Infested figs.	Uninfested.
Nights.		*Per cent.*	*Per cent.*
1	100	27	73
1	100	31	69
2	100	41	59
2	100	36	64
3	100	42	58
3	100	47	53

From these data it is apparent that in an exposure of one night 29 per cent of the figs become infested, in two nights $38\frac{1}{2}$ per cent, and in three nights $44\frac{1}{2}$ per cent. The average infestation for all figs not remaining over three nights on the "serghi" is therefore about 37 per cent.

INFESTATION IN FIG "DEPOTS."

As the figs are gathered from the "serghi" they are transported, (see Pl. VIII, figs. 1, 2) in goat's-hair bags or woven willow baskets strapped on the backs of horses or camels, to the villages, where they are dumped into large piles in buildings known as fig "depots." Here the different grades are mixed and resacked into other goat's-hair bags (see Pl. IX, fig. 1), and later loaded onto camels (Pl. IX, fig. 2) to be carried to the railroad station for shipment to Smyrna. The figs are brought to the "depots" in large quantities, and considerable forces of men and women are required to handle them. It is stated by the Turks, who have charge of the figs at this period of their manipulation and who look after their transportation to Smyrna until they are turned over to the commission men at the bazaars, that the figs never remain in these "depots" for more than 48 hours, and seldom longer than a single night. It would seem from this that the opportunity of infestation in the "depots" is necessarily small.

At about sundown August 24 a fig "depot" located at Tchifte Kaive was entered with the hope of determining whether or not the moths occurred there as abundantly as they did over the "serghi." Lanterns were used, and at about 6.30 p. m., at least 30 minutes before the appearance of the moths out of doors, they began to be active, and by 7 o'clock were fluttering in large numbers over the piles of figs and depositing eggs.

The moths are not present in these "depots" early in August before the figs have entered them. A large number of "depots" in the different villages was inspected early in August before dried figs had begun to enter them, and no sign of living Ephestia in either pupal or adult stages could be detected by the minutest examination of the dust and cobwebs in dark corners of the buildings. Unquestionably the moths are attracted into the "depots" by the odor of the first figs that enter. Finding the building to afford good shelter from heat, wind, and too much light, and furnished a fresh supply of figs each day from the orchards, they doubtless remain inside until the end of the season, increasing each day in abundance as new individuals enter from the outside. The moths are more abundant in the "depots" than outside over the "serghi," and it is astonishing that a single fig passing through the "depots" should escape infestation. If the figs were to remain for any length of time in the "depots," the amount of infestation resulting from so great an abundance of moths would prove almost startling.

INFESTATION IN FREIGHT CARS.

After leaving the "depots" the figs are tightly inclosed in goat's-hair bags until they reach Smyrna, and there is little chance for fur-

FIG. 1.—TEAM OF WATER BUFFALO AND DRIVER AND TURKISH CART, OFTEN USED FOR CARRYING FIGS. (ORIGINAL.)

FIG. 2.—FIGS ARRIVING AT A "DEPOT." BROUGHT FROM ORCHARD ON HORSEBACK BY PEASANT WHO GREW THEM. TCHIFTE KAIVE, ASIA MINOR. (ORIGINAL.

FIG. 1.—FIGS OF DIFFERENT GRADES BEING MIXED IN "DEPOT" OF INTERIOR, AND RESACKED FOR SHIPMENT TO SMYRNA.

In these buildings much damage occurs from fig moths. Tchifte Kaive, Asia Minor, August 24, 1910. (Original.)

FIG. 2.—CAMEL CARAVAN CONVEYING FIGS FROM A "DEPOT" TO RAILROAD STATION IN INTERIOR OF ASIA MINOR.

At this stage from 50 to 75 per cent of the figs are infested with eggs or larvæ, many of which are destroyed by tight packing and rough handling. (Original.)

ther infestation by moths until they are again exposed in the "khans" of Smyrna. The railroad carries them in both open and closed cars, known as "wagons." (See Pl. X, fig. 1.) During the month of August a large number of these cars was inspected for evidences of the fig moth, either in the egg, larval, pupal, or adult stages; but nothing was discovered which would lead one to believe that the freight cars are in any way responsible for the infestation of the crop. Many cars, however, were found to be very dirty, and Dr. Yenidunia, director general of agriculture, requested the railroad authorities to have all wagons, or cars, intended for the shipment of figs from the interior to Smyrna thoroughly disinfected with chlorid of lime and water before using.

On August 26, after the issuance of this order by the railroad officials, a wagon was inspected at Tchifte Kaive and found to have been sterilized and to to be in every respect clean. A loaded car of figs was also examined and several of the bags disturbed, but no fig moths were seen. The bags of figs remain in these wagons but a short time, never longer than 48 hours, and are unloaded as soon as they reach Smyrna.

INFESTATION IN BAZAARS IN SMYRNA.

After their arrival in Smyrna the bags of figs remain only a few hours in the bazaars, before being carried to the "khans" and dumped. On several occasions during the month of October close inspection was made of the interiors of closed fig bazaars in Smyrna and of conditions surrounding the bags of figs in the open bazaars in the streets. Débris and dust about dark corners were disturbed and empty sacks, strewn about the ground, were turned over or shaken, but the number of moths aroused in this way was of no consequence. Few moths were present in or about these bazaars, and they were accidental. The bags, furthermore, are well covered at the top at night with cloth or paper, so that the chances are very slight of the figs having eggs laid upon them during their brief stay at the bazaars. (See Pl. X, fig. 2.) Bags of figs are not emptied at the bazaars and seldom remain there over 24 hours. Occasionally larvæ were seen crawling over the bags, but these had come from the figs within and had not hatched from eggs laid in the bazaars.

Visits were twice made to bazaars in the evening during October and search made with lanterns, but only a few straggling moths were seen. These could not account for any infestation of the figs.

INFESTATION IN THE "KHANS."

Beginning as early as August 6, before their cleaning and whitewashing began, the "khans" in Smyrna were often and repeatedly examined for traces of the fig moth in the larval, pupal, or adult

forms. No living pupæ were found at any time before October, those seen later having resulted from the same year's supply of larvæ. Empty cocoons were found in abundance in some of the "khans" before their cleaning, but these could have no possible bearing on the infestation of the coming crop.

During August and early September the figs as they reach the "khans" are apparently free from "worms," yet if many are broken open and examined they will be found to contain young larvæ. In October conditions are different. About piles of refuse figs many full-grown larvæ may be seen crawling up the walls. (See Pl. XI, figs 1, 2.) This is not due to the fact that larvæ are more abundant in October, but that the figs have remained so long inland that the larvæ have matured and are leaving the figs to pupate. A small percentage pupates within the figs, and the adults may even issue in October in the "khans," but these moths do not cause the infestation of the crop, and are too few in number and issue too late to do any damage.

The first adult seen in a "khan" was on August 31. A single individual was found and its presence was purely accidental. Later than the middle of September adults were occasionally seen about the "khans," but in very small numbers. They were as often seen in screened "khans" as in open ones, showing that they had largely issued from figs which came into the "khans" since the first of the season.

On different occasions piles of figs in the "khans" were watched by night with lanterns and in no case were more than 4 or 5 adults seen in an evening. When we compare this with the hundreds of moths seen flying over piles of figs in "depots" of the interior there can be little question where infestation begins.

INFESTATION IN STEAMERS DURING OCEAN TRANSIT.

Further opportunity for infestation occurs while the figs are en route to America. To determine positively if they are attacked at this period a large consignment of figs was accompanied from Smyrna to New York, frequent observations being made. No Ephestia adults were seen in the hold at any time, but larvæ were commonly observed that had escaped from the boxes of figs during shipment. (See Pl. XIII, fig. 2.) No larvæ were seen about the bags of "naturals," or unpacked figs. In fact, figs shipped in bags are generally so badly crushed and macerated that no larvæ can survive in them. (See Pl. XII, fig. 1, and Pl. XIII, fig. 1.)

THE PRINCIPAL SOURCE OF INFESTATION.

To summarize, infestation of the figs begins in or near the orchards in the interior of Asia Minor, before the dried fruit has reached

FIG. 1.—CLOSED RAILROAD CAR, OR "WAGON," USED IN TRANSPORTING FIGS FROM THE INTERIOR OF ASIA MINOR TO SMYRNA.

No infestation by fig moths is possible in these cars, owing to the perfect closing of the goat's-hair bags. (Original.)

FIG. 2.—AN INDOOR FIG BAZAAR AT SMYRNA.

Figs are not exposed to moth attack in the bazaars, owing to the sacks being well closed. (Original.)

FIG. 1.—PILE OF REFUSE FIGS IN A SMYRNA "KHAN."

On the walls above these figs fig-moth larvæ congregate in large numbers. (Original.)

FIG. 2.—GREEK WOMEN GRADING THE REFUSE FIGS IN A SMYRNA "KHAN."

All grades, however filthy and wormy, are exported for use as food. (Original.)

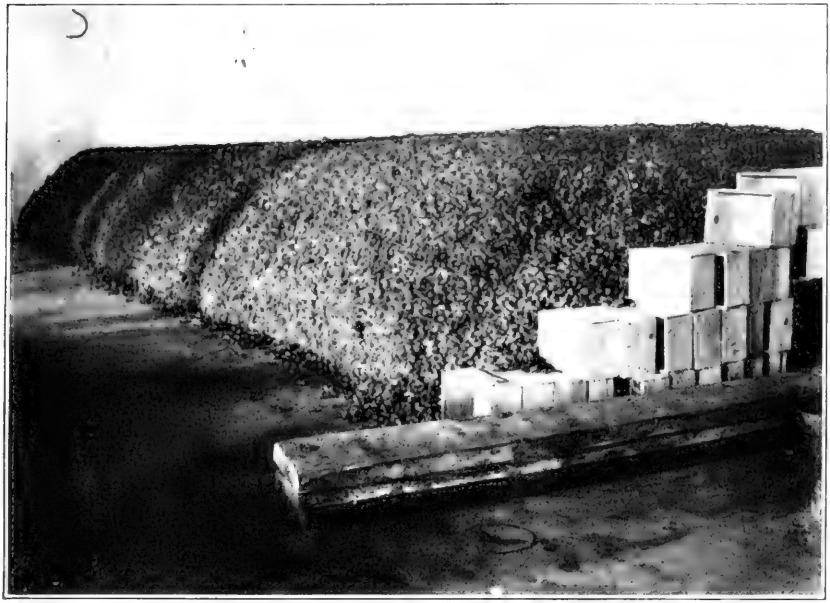


FIG. 1.—LARGE "PACIALE" OF NATURAL (DRIED) FIGS READY TO SACK FOR EXPORT, IN A FIG "KHAN" IN SMYRNA.

These figs are shipped in jute bags, and the larvæ that remain in them are destroyed in transit to America. (Original.)

FIG. 2.—NATURAL (DRIED) FIGS BEING WATERED AND MIXED, SHOWING METHOD OF HANDLING WITH WOODEN SCOOPS OPERATED BY MEN IN BARE FEET.

The salt water causes the larvæ to leave the figs and crawl up the walls. (Original.)

FIG. 1.—THOUSANDS OF BAGS OF NATURAL (DRIED) FIGS IN A SMYRNA "KHAN" INTENDED FOR EXPORT TO AMERICA TO BE MADE INTO "STRAWBERRY" AND FIG JAM.

Larvæ smother in these bags and do not escape from the figs. (Original.)

FIG. 2.—SKELETON CASES OF SMYRNA LAYER FIGS BOUND FOR AMERICA IN HOLD OF MEDITERRANEAN STEAMER AT GENOA.

Larvæ escape from the cases and pupate in the hold, but adults developing from them perish before the next year's figs are shipped. (Original.)

Smyrna to be packed. Out of 100 worm-infested figs, the larvæ in possibly 5 to 10 per cent of them might be traced to the tree, while the other 90 to 95 per cent of larvæ develop from eggs laid either while the figs are on the "serghi" or in the fig "depots" of the villages. The number of larvæ originating from eggs laid while the figs are in freight cars en route to Smyrna, in the packing "khans" of Smyrna, or in the holds of steamers en route to America, is inconsiderable.

METHODS OF CONTROL.

The real source of infestation determined, the question arises as to the best means of avoiding it. Spraying with insecticides or fumigating the trees by using tents is too expensive for the average peasant and would be, furthermore, of little use where so small a percentage of infestation occurs on the tree, unless these methods could be employed at a time when they would kill the first generation of the insect, which is confined exclusively to the orchard. Efforts must be directed to some means of destroying the adults that cause the infestation, or of reducing their numbers by a systematic attack upon the larvæ or pupæ from which they mature—i. e., by reduction of the early stages of the earlier broods of the moth in the orchard.

DESTRUCTION OF THE EARLIER BROODS OF THE MOTH.

Upon questioning a number of Turkish peasants at Tchifte Kaive it was learned that there is an earlier crop of figs produced by the majority of trees in the latter part of May and largely throughout June. These figs are rather larger than the drying figs that later appear on the same trees, but are insipid and much more watery, and, therefore, useless for drying purposes. Being of little export value, few, if any, of them ever reach Smyrna, so that such as are not used by the peasant for his own consumption are allowed to remain in the orchard and spoil on the ground. These figs are reported to be very "wormy;" in fact the Turkish word applied to the early crop, which to the merchants is known as the June crop, is a term meaning "wormy figs." There can be little doubt that the June crop of figs furnishes sustenance for the early broods of the fig moth, and is responsible for the myriads of moths which later appear to infest the valuable export crop ripening in August and September. How many generations of the moth breed in the June crop of figs it is impossible to say, but probably at least two.

It is of great importance that rigid regulations be enforced upon the peasants for the quick disposal or destruction of the June figs as they drop from the trees in order to diminish so far as possible

the number of moths which breed from them. Whether or not these figs can be put to any other use than simply being eaten raw by the peasants is yet to be learned, but if so it would be of great value and an effectual means of reducing infestation to the autumn or export crop.

PROTECTION OF DRYING FIGS.

Covering the figs at night, while they are drying on the "serghi," would very much reduce their "worminess." A practical way of doing this would be to adopt frames for the drying as used in California, which could be stacked one over the other each evening. Where this is found too expensive, a covering of cloth of mesh close enough to prevent oviposition, spread over the figs each evening and held down with weights, would do much to exclude the moths and thus prevent the deposition of eggs on the figs. But even this simple treatment, in order to give results, should be uniformly applied by all growers. The effect of such a treatment would be to divert the moths to the orchard; but their consequent scattering, and the much greater time that would be required for them to deposit eggs upon the same number of figs on the trees, would result in a marked diminution of the damage.

EXCLUDING MOTHS FROM FIG "DEPOTS."

As a special precaution against infestation of figs in the "depots," the latter were ordered by the director general of agriculture to be thoroughly disinfected throughout with chlorid of lime and whitewashed before any figs should enter them, as required in the packing "khans" of Smyrna. Measures of precaution such as these for the destruction of eggs and cocoons already in the "depots" are practically useless, as the buildings bear no living traces of the moths at the beginning of the season, and as practically no moths are brought in with the figs, the majority must enter by night through the open doors and windows. A careful screening of these and closing of all stray openings about the roof and under the gables in July or the early part of August, before the figs have entered, would exclude practically all moths from the fig "depots" and very considerably reduce the amount of infestation to figs.

DESTRUCTION OF EGGS ON FIGS.

Even with close adherence to the precautions advised above, namely, the covering of figs on the "serghi" and careful screening of the "depots," many figs will become infested with eggs before they leave the "depots," for the moths will find access to the fruit while on the tree, or while on the ground in the orchard before being

gathered. The only way to insure figs against some infestation is to destroy the eggs present on them before sacking them for shipment to Smyrna. An experiment was made to determine the temperature and length of exposure (boiling in salt water) necessary to kill the eggs.

From figs that had been exposed from one to three days on "serghi," at Tchifte Kaive, August 24, a large number was chosen bearing Ephestia eggs adhering to the skins. These were boiled, in small lots, in water containing 2.5 per cent of salt, for the following lengths of time at different temperatures:

Lot.	Exposure.	Temperature.		Lot.	Exposure.	Temperature.	
		°C.	°F.			°C.	°F.
1	30 seconds.	70	158	5	1 minute..	70	158
2	...do......	80	176	6	...do......	80	176
3	...do......	90	194	7	...do......	90	194
4	...do......	100	212	8	...do......	100	212

After taking them from the water they were hung in large-meshed bags to dry in the wind and sun. When examined August 25, the eggs in lots 3, 4, 6, 7, and 8 had entirely collapsed, and were partially collapsed or at least dented in lots 2 and 5. The eggs in lot 1 were apparently unharmed by the heat, but two days later were discolored perceptibly, and showed no signs of vitality. By September 3 larvæ were working in almost every lot of figs experimented upon, but these had undoubtedly hatched and entered the figs previous to the boiling, as they were too old to have come from eggs present on the outside of the figs when they were boiled. The conclusion is that boiling the figs in water containing $2\frac{1}{2}$ per cent salt for an exposure to exceed 30 seconds and temperature to exceed 80° C. (176° F.) will kill all eggs on the outside of the fig, but will not kill larvæ within the fig, even though the temperature is increased 20° C. (36° F.).

DISCONTINUING THE RETENTION OF FIGS INLAND.

Between the fig "depot" of the interior and the packing "khan" of Smyrna measures of precaution against worm infestation are unnecessary, as the moths have no access to the figs while they are in the goat's-hair bags. Promptness in delivery to the packers is the all-important thing to be observed at this period of the fig's handling. Two weeks' delay brings most disastrous results. During this time the worms which have hatched from eggs laid on the "serghi" or in the "depots" are doing their worst damage and are growing rapidly to a size that renders their presence in the figs most offensive. Moreover, the physical condition of the fig is injured by delay in shipment to Smyrna.

After inquiry, the writer is convinced that the railroad is able to transport the fig crop direct to Smyrna as promptly as it comes to the villages from the orchards, and that the packers in Smyrna are quite as able to handle it as fast as it can be turned over to them. From our point of view there is no reason, therefore, why figs should be detained in the interior unventilated in the bags, or in piles in the fig "depots" exposed to moths, flies, and other sources of contamination. A week's time is more than sufficient for the figs to reach the packer after they have been gathered from the "serghi." Observations show that most of the crop is held in the interior some time after harvesting, in many cases more than a month. The object of this is to bring better prices to the growers and the middlemen, at the expense of the packers, and to correspondingly increase the revenues to the local Government, regardless of what the consequences may be to the product or to the consumer.

The practice of "holding" the figs by the producers and middlemen is of recent origin, and apparently is growing. So long as the responsible parties realize large profits from such a practice, as they undoubtedly do, it is not likely to be discontinued, except by stringent action on the part of those who consume the figs and are forced to pay highly for the injuries done. The packers are in no position to control the supply, and can do nothing better than to take whatever figs they can get from the peasants and their representatives, at such time and price as offers, charging a correspondingly higher price for the packed figs. Americans may expect in the future to pay a higher price for figs inferior to those now imported, unless some decisive action is taken to stop this unwarranted retention of the crop inland.

ELIMINATION OF LARVÆ IN THE "KHANS."

The Smyrna "khan" is not responsible for the wormy condition of figs. But as the packer is responsible for the fig reaching the consumer, he also must be held accountable for the condition in which it reaches the consumer. If the fig is laden with "worms," he must rid it of these before it can be imposed upon the public as a sanitary article of diet. The experiments conducted in the "khans" were undertaken with the hope of discovering a means by which the packers could profitably furnish the American importers with sanitary figs, free from fig "worms" or other insect pests.

In contemplating a means of eradicating larvæ from figs in the "khans" considerable dependence was placed upon the method used in this country for freeing flour mills of the related Mediterranean flour moth (*Ephestia kuehniella*), viz, by hydrocyanic-acid gas fumigation. After examining the "khans" several reasons were found why the fumigation method could not be used: (1) Whatever ventilation openings occur near the roofs in these buildings are not

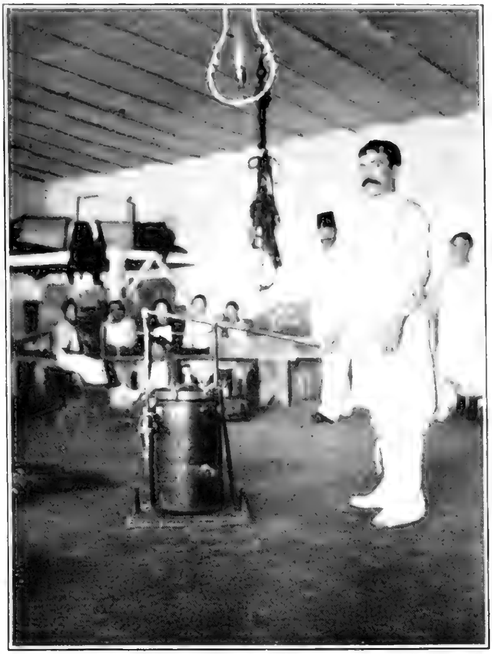


FIG. 1.—A HAND VACUUM MACHINE FOR EXTRACTING AIR FROM JARS OF FIGS, AND ITS OPERATOR.

Larvæ do not survive in jars of figs so treated. (Original.)

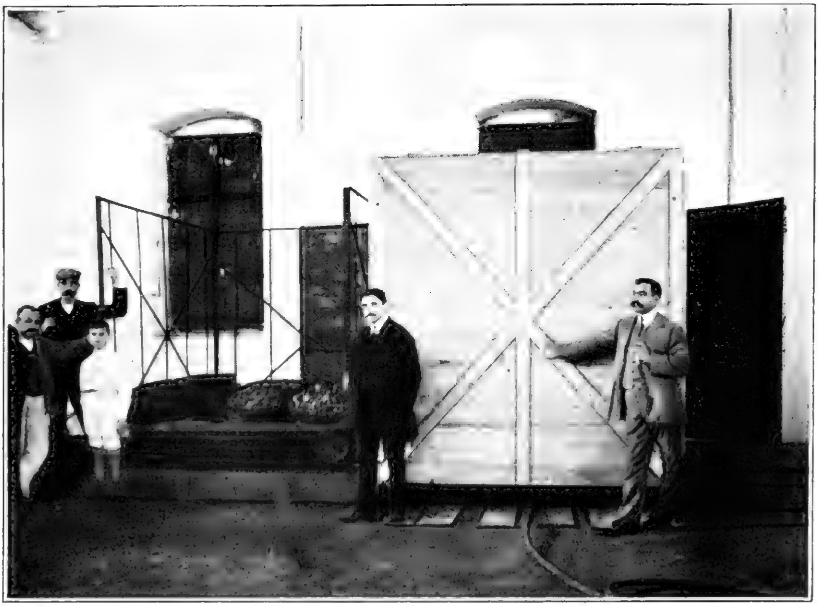


FIG. 2.—OVEN FOR STERILIZING FIGS BY DRY HEAT, WITH LOADING FRAME EXTRACTED; EMPLOYED IN A "KHAN" IN SMYRNA.

By subjection to dry heat a very large proportion of larvæ in the figs is destroyed. (Original.)

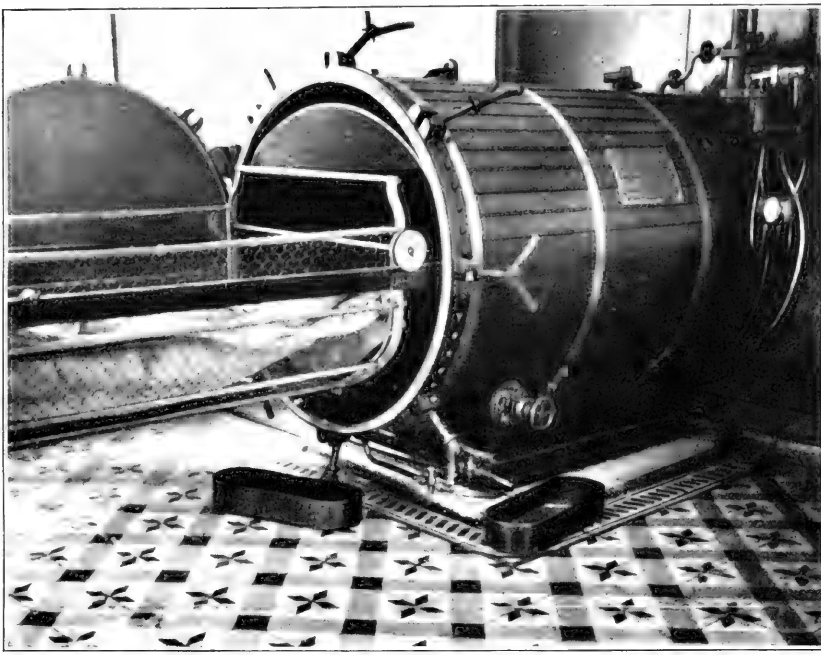


FIG. 1.—STEAM DISINFECTING CLOSET, WITH LOADING FRAME EXTRACTED, WHICH COULD BE EASILY ADAPTED FOR STERILIZATION OF FIGS AND DESTRUCTION OF FIG-MOTH LARVÆ. (ORIGINAL.)

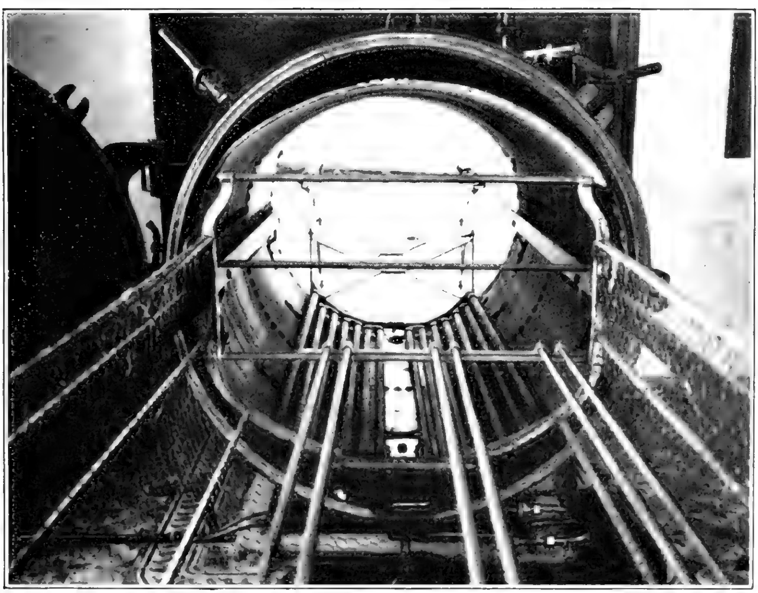


FIG. 2.—INTERIOR OF STEAM DISINFECTING CLOSET WITH ENDS OPEN AND LOADING FRAME EXTRACTED, SHOWING ARRANGEMENT OF PIPES WITHIN. (ORIGINAL.)

furnished with glass and are often so large that it is impossible to make them air-tight; (2) the supply of figs in a "khan" does not remain, but passes through in a very short time, usually a day or two, which would necessitate fumigating several times a week. This would be too expensive a process, as well as impracticable, because it would endanger the occupancy of the building the following day. The proportion of air space in a "khan" to the amount of figs to be treated would make fumigation totally impracticable (Pls. XII, fig. 2, and XIII, fig. 1), and the packers are emphatically opposed to subjecting their wares to the action of such deadly fumes as those of hydrocyanic acid.

EXPERIMENTS IN THE "KHANS."

The simplest possible treatment for the destruction of foreign life in any article of food, viz, subjection to heat, suggests itself as more economical and easier to apply than any other method. Experiments were made using three distinct methods of application, i. e., by steam, hot water, and hot air. The results obtained by using any of these do not vary greatly, though the details of the application, the required temperatures and lengths of exposure, and the drying where water is used, necessarily differ much. Experiments were also made using a vacuum treatment.

In conducting experiments for the eradication of fig-moth larvæ by various methods the writer was extended many courtesies by packers of figs in Smyrna, some of whom had been using the same methods with practical results for some time, and had apparatus in their establishments for the purpose. In one case an expensive sterilizing outfit was installed for the special purpose of making experiments to determine the practicability of subjecting figs to special treatment to kill the "worms." Among Smyrna fig packers, who seemed particularly interested in this phase of the fig industry and to whom the writer is indebted for material assistance in performing the experiments, may be mentioned Mr. John Manola, Mr. Aram Hamparzum, and the manager of his "khan," Mr. Vedova; Messrs. A. Reggio and sons, and Mr. S. A. Stassinopulo.

DESTRUCTION OF LARVÆ BY VACUUM TREATMENT.

Attempts were made to free the figs of "worms" by subjection to vacuum, but with little success. An experiment was performed on September 26, in a "khan" in Smyrna, to determine whether vacuum treatment could be successfully applied to layer figs in boxes to kill the larvæ present. A number of larvæ, found crawling up the wall above a pile of refuse figs, was inclosed in a fig jar, and put into a

vacuum machine, and the air extracted from the jar. (See Pl. XIV, fig. 1.) A day later the larvæ were alive and apparently healthy, but were quite inactive. On September 30 they were still alive and healthy, but seemed able to move only the fore part of the body, and that very feebly, spinning silk about them in apparent effort to make cocoons. When examined on October 8 they were in the same positions they had had a week previously; but by this time they showed almost no movement, at least no more than feeble agitation of the head, in evident discomfort. They had shrunken from their former size, and some had spun abundant silk; but none of them retained sufficient energy to spin a cocoon. They looked very sick, but were all living. By October 21 they were still more shrunken, and a few of them quite lifeless, though the majority showed by their color that they were not dead.

From the experiment it is plain that larvæ, though they might survive, would not continue to feed and to do damage if the vacuum were sustained about them. The application of a vacuum treatment to figs in boxes, however, would prove quite useless, since the larvæ would immediately revive and become active when brought back into the air. To render the larvæ inactive and thus innocuous, the vacuum must be long sustained, which is possible only by putting all figs in glass jars—a very expensive process.

RIDDING FIGS OF LARVÆ BY STEAM.

Experiments were made, October 6, to determine whether larvæ may be killed by subjection of infested figs to steam in confinement in a large steam disinfecting closet used in a Smyrna hospital for sterilizing clothing. The closet was tubular in form and horizontal, both ends opening to allow the entrance of one loading cage filled with clothing, while the other was being extracted at the opposite end for reloading. (See Pl. XV, figs. 1, 2.) The loading cages ran on rails on frames at each end of the closet, adjustable to similar rails inside. The steam was applied from an adjoining boiler, the pressure being allowed to reach about 10 pounds, at which point the temperature of the steam was 115° C. (240° F.).

A number of "natural" (dried) figs that showed traces of the presence of larvæ within them was introduced into the centers of two 25-pound jute bags of figs. The first bag was allowed to remain in the steam closet under full pressure of steam for 10 minutes, the second for 30 minutes.

When the first bag of figs was examined following the steaming the larvæ were found dead in all infested figs within 3 inches of the surface of the bag. Of 18 larvæ taken from figs at or near the center

only 3 were dead. Five more, that were stupefied, slowly recovered. In the bag exposed 30 minutes all larvæ near the surface were dead. Of 15 larvæ taken from figs at the center of the bag 13 were dead, or so badly injured that they did not revive, and the other 2 were sickly.

The following table gives percentages of larvæ killed by the steam at center of bag:

Temperature.		Exposure in minutes.	Number of larvæ.	After scalding.		Per cent killed.
°C.	°F.			Living.	Dead.	
115	239	10	18	15	3	17
115	239	30	15	2	13	87

When the bags of figs were taken from the steam closet they were badly soaked with water, those portions not dumped remaining wet for hours and the figs remaining very sticky and disagreeable.

Samples of figs scalded by steam were sent, about October 20, to Washington. At the time of sending, those scalded for 10 minutes were almost dry, while those scalded for 30 minutes were still damp. Examined by the writer in Washington, two months later, the figs were nicely sugar-coated; but it was noticed that all broken or injured figs, as well as many that were uninjured, were badly soured.

The conclusion is drawn that it is practically impossible to successfully sterilize figs by steam while in bags. The presence of so many soured figs among those experimented upon seems to make the practical use of steam doubtful, however well this destroys the larvæ. Artificial drying of the figs following their scalding would probably prevent the souring. Steam has an advantage over hot air in destroying larvæ in that a very short time is required to apply it and to raise the temperature to the degree desired. In addition, steam has more penetrative power than hot air, and hence requires shorter exposure of the figs.

SCALDING FIGS IN HOT WATER TO KILL LARVÆ.

The most extensive experiments were made with hot water. One fig-packing establishment in Smyrna has in operation apparatus for the sterilization of figs by boiling water, and good results were obtained from experiments made there in killing the larvæ. (See Pl. XVI, figs. 1, 2.) The required exposure is much shorter than for either steam or dry heat, and the subsequent drying easy. By this process a large percentage of the "worms" in figs can be destroyed without the additional expense in manipulation of much over a shilling (25 cents) per hundredweight, and if done on a large scale

the cost can be reduced. This estimate is based upon figures furnished by a packer who uses the process.

In the first experiment the exposure of the figs in the boiling water was very much undertimed. A number of figs infested with larvæ, selected from a pile of refuse and "hordas"[a] in a "khan," was immersed in boiling salt water (2.5 per cent solution, containing also some glucose) at 100° C. (212° F.) for short periods at varying temperatures, then put into jars and watched to determine what would later breed from them. The following table gives the temperatures and lengths of exposure and the number of larvæ that emerged at intervals of a week or more:

Temperature, lengths of exposure, and number of larvæ that emerged from scalded figs at intervals of a week or more.

Temperature.	Exposure.	Number of figs.	Number of larvæ present.						Per cent killed.
			Sept. 15.	Sept. 20.	Sept. 26.	Sept. 30.	Oct. 8.	Oct. 28.	
° C.	*Seconds.*								
100	10	10	......	......	1	2	3	4	60
90	10	11	2	3	7	10	11	13	0
80	10	11	1	2	2	7	7	7	0
70	10	8	......	3	5	6	7	7	0
100	5	9	2	5	12	17	19	19	0
100	1	9	1	1	3	7	8	10	0
Check.	Check.	7	......	2	3	5	6	9	0

Since the number of larvæ present in the figs before boiling was plainly variable, the only conclusion reached by this experiment is that an exposure of 10 seconds in water at 100° C. (212° F.), while it may reduce the number of larvæ in the figs somewhat, is quite insufficient to kill all of them, and that exposures for shorter periods or at lower temperatures than that are practically useless.

In another experiment figs similarly infested with larvæ were immersed in water containing 2½ per cent of salt and a small amount of glucose, boiling at 100° C. (212° F.) for 20, 25, and 30 second periods. But these exposures, likewise, proved insufficient. Those scalded for 20 and 25 seconds, when broken open after the immersion, were found still to contain living larvæ. In the figs boiled 30 seconds that were broken open immediately the larvæ were apparently all dead.

[a] Figs which have failed to mature on the trees, and which consequently contain no sugar, being dry, hard, and flavorless.

FIG. 1.—COPPER BOILERS AND GALVANIZED STRAINERS USED FOR STERILIZING FIGS IN A SMYRNA "KHAN." THE PERCENTAGE OF LIVING LARVÆ IN THE FIGS IS MUCH REDUCED BY SCALDING. (ORIGINAL.)

FIG. 2.—INTERIOR OF OVEN FOR DRYING TRAYS OF FIGS WHICH HAVE BEEN STERILIZED BY BOILING, USED IN A FIG "KHAN" IN SMYRNA. (ORIGINAL.)

The following table shows the number of fig-moth larvæ that later developed from figs boiled in this experiment:

Temperature.	Immersion.	Number of figs.	Immediate effect.	Larvæ present Oct. 28, 1910.	Per cent killed.
° C.	Seconds.				
100	20	18	Larvæ living......	11	39
100	20	18	.....do............	[a] 8	56
100	25	17	Mostly living......	7	59
100	25	17	.....do............	10	41
100	30	14	Mostly dead.......	[a] 5	64
100	30	14	.....do............	10	29

[a] Omorga.

Examination of the figs immediately following the immersion would seem to show that a much larger percentage of the larvæ is killed by an exposure of 30 seconds in the water than by shorter exposures, though the number of larvæ breeding from figs scalded for 30 seconds does not lead to the same conclusion. The percentages killed can not be accurate, since in figuring them it is assumed that each fig contained a single larva, when in fact the number of larvæ in a fig is variable. Plainly an exposure of 30 seconds of infested figs in boiling water is not sufficient to kill all larvæ within the figs. Unfortunately, this fact was not established by the emergence of larvæ from the boiled figs until the season was too far advanced to make further experiments allowing longer exposures in the hot water.

If larvæ were not killed in figs immersed for 30 seconds in boiling water it was because the heat did not penetrate to the interior of the fig in that length of time, for contact with water at boiling temperature causes immediate death to any larva. To determine how many seconds or minutes are required after immersion for the interior of the fig to rise to the temperature of the water, the bulb of a high-temperature thermometer was inserted to the center of 3 large figs successively, which were immersed in water at 100° C. (212° F.) and the temperatures recorded every half minute. The first fig was immersed in a large sterilizing kettle at a "khan" and the temperatures recorded for only 7½ minutes. The others were immersed in a small vessel of boiling water in the laboratory and the temperatures recorded for periods of 16 minutes.

The following table gives the rate of rise in temperature of the interior of the three figs and the resultant average rise. The average for periods of over 7½ minutes is taken from two figs only:

	Temperature readings.			Average temperature.		Rate of increase in temperature.
	No. 1.	No. 2.	No. 3.	Centigrade.	Fahrenheit.	
Minutes.	° *C.*	° *C.*	° *C.*	°	°	° *C.*
(*a*)	45	20½	20½	28⅓	83	....
½	50	27	28	35	95	12
1	55	41	39½	45⅙	113	18
1½	60	53	49	54	129	16
2	65	63	57	61⅔	143	14
2½	70	71½	63½	68⅓	155	12
3	74	77½	69	73½	164½	9½
3½	78	82½	74	78⅙	172¾	8¼
4	81½	86½	77¾	82	179½	6¾
4½	84½	89½	81¼	85	185	5½
5	86	92	83¾	87¼	188¾	3¾
5½	87	94	86¼	89	192	2¼
6	88	96	88½	90⅚	195	2
6½	89	97¼	90¼	92⅙	197¾	1¾
7	90	98¼	91⅞	93⅓	200	1¼
7½	91	99¼	93¼	94½	202	1
8	....	100	94½	97¼	207	....
8½	....	100½	95½	98	208⅓	1⅓
9	....	101	96½	98¾	209⅔	1⅓
9½	....	101⅜	97½	99⅜	211	1⅓
10	....	101¾	98¼	100	212	1
10½	....	102⅛	99	100½	213	1
11	....	102⅜	99½	100⅞	213⅔	⅔
11½	....	102⅝	100	101¼	214⅓	⅔
12	....	102⅞	100⅜	101⅝	215	⅔
12½	....	103	100¾	101⅞	215½	½
13	....	103⅛	101⅛	102⅛	216	½
13½	....	103¼	101½	102⅜	216⅓	⅓
14	....	103¼	101⅞	102⅝	216⅔	⅓
14½	....	103⅜	102¼	102⅞	217	⅓
15	....	103⅜	102½	103	217¼	¼
15½	....	103⅜	102¾	103⅛	217½	¼
16	....	103½	102⅞	103¼	217¾	¼

a At immersion.

Since the rise of temperature was variable in the three figs, to reach more nearly the exact rate of rise an average was taken of recorded temperatures from all. Thus, for the interior temperature to reach 90° C. required in the first fig 7 minutes, in the second 5 minutes, and in the third 6½ minutes. For the interior of the average fig to reach 90°, therefore, would require about 6 minutes.

That 100° C. is necessary to cause immediate death to larvæ does not mean that figs must be boiled 10 minutes to kill the larvæ in them. Larvæ will as surely succumb to a temperature of 90° C., if sustained for a longer period, as to 100° C. in a short period. The accumulative heat at lower temperatures of the fig up to the point where the "required" temperature is reached has a decided devitalizing effect upon the larva. In boiling figs, larvæ will perish some time before an interior temperature of 100° in the figs is reached. Therefore it must be learned by further experiment what temperatures below 100° C., sustained for what lengths of time, will prove

fatal to larvæ before it can be stated exactly how long figs must be boiled to kill the larvæ inside of them.

Many packers complain that figs which have been boiled in hot water sour in a few weeks. If this be true, it is because the figs are boiled too long, i. e., longer than is necessary to kill the insects. Figs scalded by the writer in early September had up to December 20 shown no indication of souring.

The experiments that were made to determine the exact effect upon figs of boiling them to kill insect larvæ were performed in one of the larger "khans" in Smyrna. Two 5-pound boxes of layer figs, one of "4-crown" and one of "7-crown," and another box of "Locoum" figs were boiled and packed in the presence of the writer. Three identical boxes of figs that were not boiled were also packed the same day for use in "checking" the experiment, and all were shipped to Washington, D. C., for later observation and comparison. The figs were scalded in a 2.5 per cent salt solution at a temperature of exactly 100° C. (212° F.) (taken by a high-temperature thermometer) for 10 seconds, then drained and put into a screen-bottomed drying tray and immediately carried into the packing room. When first taken from the hot water they had apparently absorbed a small amount, making the skin semitranslucent. Packing began exactly 5 minutes after the scalding. By this time all excess moisture on the outside had evaporated except that held in the cracks and folds of the skin. Ten minutes later the remaining moisture had also evaporated. At this stage the figs differed from those not scalded in that the skin was quite translucent, as though retaining a small amount of moisture, and in being rather less sticky and far softer and more flexible, and easier to pack into layers.

When the boxes of scalded figs were opened up the following January and February in Washington they were in prime condition and noticeably free from attack of larvæ. The only objections to them were their stickiness and a very slight flavor of acidity noticeable in some figs. In spite of these objections they were cleaner and much preferable to the figs not boiled.

Some packers contend that boiled figs are darker in color and, therefore, less desirable; but so long as the figs are not injured in quality by the boiling, it is reasonable to believe that their freedom from "worms" will more than compensate the loss in color. Almost all packers boil the figs intended for their own consumption, but strangely can not afford to boil those intended for sale, or find reasons not to do so.

APPARATUS FOR STERILIZING WITH HOT AIR.

Dry heat has proved to have advantages over the hot-water method. The time wasted in the subsequent drying of the figs is eliminated,

and there is less tendency for the fruit to acidify, as occasionally occurs when it has been boiled. The color, too, is if anything less affected by dry heat; though this is difficult to determine positively, as experiments were made with a different lot of figs from those boiled, and under different conditions. The disadvantage of the dry-heat process as compared with hot water is the much greater exposure required, since time is an important item in the figuring. It is also more difficult to maintain a uniform temperature. Another respect in which the dry process is inferior is that it does not remove filth and destroy microbes on the outside of the fig, as does boiling.

At a large khan in Smyrna has been installed an oven, heated by gas, for experimental work in the destruction of fig-moth larvæ in figs. The dimensions of the oven are 2 by 2 meters by 3 meters long. Both ends open out, and are furnished with double doors that swing vertically. Passing through the oven is a track of two rails 1¼ meters apart, on which run two iron loading frames on wheels. The capacity of each frame is about 4 to 5½ tons, depending on whether the figs are loaded in sacks or in the woven baskets piled one above the other. The object of having two frames is that one may be reloaded while the other is within the closed oven and the figs are being sterilized. The oven is made of sheet iron 4 mm. thick. The doors are covered outside with sheet asbestos, with an air-space 1¾ inches in depth between it and the sheet iron. The sides and top are covered with white planking three-fourths of an inch thick set out from the sheet iron, with intervening air spaces of depths of 6¼ and 4½ inches respectively at sides and top. The object of the air spaces is to prevent burning of the wood and radiation and loss of heat. Paper put into these air spaces, with asbestos next the iron, would still further conserve the heat. The oven is heated by gas, which is furnished by a large series of burners on a sliding frame that passes under the oven. Two thermometers are inserted in one of the doors, by which the interior heat may be determined and regulated. The entire cost of the oven was about £400, and the cost of the gas is about £3 for each 10 hours of use.

Considerable loss of heat accompanies each opening of the doors and insertion or extraction of the loaded frames. To ascertain the extent of this loss and the relative length of time required for the heat to again rise to a point sufficient to kill larvæ, a loaded frame was inserted in the oven and a tabulated record made of the temperatures, taken at intervals of every quarter or half minute during its exposure of 10 minutes and an additional period after its extraction.

The following figures give the temperatures of the interior of the oven before and during the introduction of the figs, and the

time required for the temperature to rise after the figs are removed:

	Time.	Temperature.		Rise (+) or drop (−) each half minute.
		°C.	°F.	°F.
Doors opened	11.50 a. m.	132	270	....
Figs introduced	11.50¼	120	248	....
Doors closed	11.50½	110	230	−40
Figs in oven	11.50¾	100	212	....
Do	11.51	97	207	−23
Do	11.51½	95	203	− 4
Do	11.52	94½	202	− 1
Do	11.52½	95	203	+ 1
Do	11.53	96	205	+ 2
Do	11.53½	98	208	+ 3
Do	11.54	100	212	+ 4
Do	11.54½	102	215	+ 3
Do	11.55	103	217	+ 2
Do	11.55½	104	219	+ 2
Do	11.56	105	221	+ 2
Do	11.56½	106	222½	+ 1½
Do	11.57	106¾	224	+ 1½
Do	11.57½	107½	225½	+ 1½
Do	11.58	108¼	227	+ 1½
Do	11.58½	109	228⅓	+ 1⅓
Do	11.59	109¾	229⅔	+ 1⅓
Do	11.59½	110½	231	+ 1⅓
Do	12.00 noon.	111¼	232¼	+ 1¼
Doors opened	12.00½ p.m.	112	233½	+ 1¼
Figs removed	12.01	94	201	−32½
Doors closed	12.01¼	92	197½	....
Oven empty	12.01½	92	197½	− 3½
Do	12.01¾	94	201	....
Do	12.02	97	206½	+ 9
Do	12.02¼	100	212	....
Do	12.02½	104	219	+12½
Do	12.02¾	108	226	....
Do	12.03	111½	232	+13
Do	12.03½	117½	243	+11
Do	12.04	121½	251	+ 8
Do	12.04½	125	257	+ 6
Do	12.05	128	262	+ 5
Do	12.05½	130¼	266	+ 4
Do	12.06	132	269½	+ 3½
Do	12.06½	133½	272½	+ 3
Do	12.07	135	275	+ 2½
Do	12.07½	136	277	+ 2
Do	12.08	137	279	+ 2
Do	12.08½	138	280½	+ 1½
Do	12.09	138¾	282	+ 1½
Do	12.09½	139½	283	+ 1
Do	12.10	140	284	+ 1
Do	12.10½	140¼	284½	+ ½
Do	12.11	140½	285	+ ½
Do	12.11½	140⅝	285¼	+ ¼

The results of the experiment are more variable than constant. The temperature dropped 40° F. during the first opening of the doors, and 28° more after the doors were closed, due no doubt to the heat required to bring the frame and figs up to the temperature of the oven. During the second opening of the oven the temperature dropped 36°, and rose immediately, as no more figs were introduced, hence no heat absorbed, after the doors were closed. From the minimum heat, 202° F., to the maximum heat, 233.5° F., the temperature of the loaded oven rose 31.5° in 8 minutes. The temperature of the empty oven rose 85.5° in the same length of time, or from 197.5° to 283° F.

The following table gives some idea of the comparative time required for the temperature to rise in the loaded and empty ovens:

	Temperature when doors closed.	Minimum temperature.	Maximum temperature.	Average temperature in 10 minutes.	Total rise in 10 minutes.	Average rise per minute.	Average rise, minimum to maximum.
Loaded	110° C.	94½° C.	112° C.	103⅘° C.	2° C.	⅕° C.	2⅕° C.
	230° F.	202° F.	233½° F.	219° F.	3½° F.	⅓° F.	4° F.
Empty	92° C.	92° C.	140⅝° C.	127½° C.	48¾° C.	4 9/10° C.	4 9/10° C.
	197½° F.	197½° F.	285¼° F.	260½° F.	87¾° F.	8 8/10° F.	8 8/10° F.

To establish definite laws for the working of the oven upon this experiment would be dangerous. If the rise in temperature of the loaded oven were uniformly 4° F. per minute after the minimum had been reached, the conclusion would be that in order to maintain the temperature of the oven it must be allowed to rise 68° between reloadings, which is the amount of heat lost during and following the reloading. If the total rise in temperature of the loaded oven is only 3.5° in the first 10 minutes, then the figs must remain in the oven at least 16 minutes longer in order for the oven to regain, at a rate of 4° per minute, the other 64.5° of the 68° lost. This would require a total exposure of the figs of 26 minutes. But as the rise in temperature of the loaded oven would without doubt accelerate after the minimum heat had been well passed, the real required exposure of the figs would be between 20 and 25 minutes. If the figs were exposed longer than this, with the gas burning at the rate employed in the experiments, the heat of the oven would increase or accelerate with each load of figs until a certain constant of equilibrium was reached. This constant could, however, be regulated by limiting the flow of gas and thus cutting down the source of the heat.

SUCCESS OF HOT-AIR TREATMENT IN KILLING LARVÆ.

A number of experiments was made to determine the temperature and length of exposure necessary to destroy larvæ by dry heat in an oven. The first of these was performed on September 21 in Smyrna, using the oven described above. A number of figs showing the presence of larvæ was chosen from a pile of refuse in a "khan" and subjected to dry heat for varying lengths of time at different temperatures.

The following table gives the lengths of exposure, the temperatures, and the number of larvæ that issued from the figs after treatment:

Temperature.			Average temperature.	Length of exposure.	Number of figs.	Number of larvæ present.		Per cent killed.
Maximum.	Minimum.	Average.				Oct. 16.	Oct. 28.	
°C.	°C.	°C.	°F.	Minutes.				
132	92	112	233	20	13	0	0	100
121	93	107	224	15	8	0	0	100
112	94	103	217	10	8	0	1	87
94	82	88	190	5	10	8	14	0

It is plain that any exposure to exceed 224° F., for 15 minutes, will destroy the life of practically all larvæ present in the figs. This exposure, however, apparently has no injurious effect upon the fruit.

A quantity of figs sterilized in the same oven by the management of the "khan" in which it is located was shipped to one of their New York representatives for examination and report. These figs were exposed for 15 minutes at an average temperature of about 212° F. Six boxes of them were forwarded to the Lederle laboratories, whose report on their condition, dated November 1, 1910, is summed up in the following table:[a]

Treatment.	Style of packing.	Number of figs.	Percentage showing evidences of larvæ.	General condition of the figs.
Unsterilized	Layer	100	12	
Sterilized	...do	100	None.	Less fermentation in top layers. More fermentation in bottom layers.
Unsterilized	...do	84	6	Contain living molds.
Sterilized	...do	89	None.	Clean and moist; no molds. Slightly greater fermentation.
Unsterilized	Macaroni	85	79	
Sterilized	...do	68	56	Slightly greater fermentation.

In the layer figs sterilization by hot air destroyed all larvæ in the two boxes examined. In case of the "macaroni" figs the same treatment reduced the number of larvæ present over 25 per cent without perceptible injury to the figs. These results argue very strongly for the use of dry heat, in preference perhaps even to steam or hot water, in ridding dried figs of the objectionable larvæ.

PRACTICABILITY OF STERILIZING ALL FIGS IN SMYRNA.

Some packers hold that in sterilizing figs the dead bodies of larvæ remain to decay inside the fruit, whereas if not killed the larvæ

[a] These figures were given by kind permission of a dealer of figs in New York City.

escape from the boxes during transit to America, leaving behind only their borings and excrement. This objection is not a reasonable one: First, because in fact a very small percentage of larvæ escapes in transit, the majority remaining within the boxes and crawling over and littering many more figs than are required for their sustenance; secondly, the body of the dead larva either dries or becomes perfectly preserved by the sirup of the fig and indistinguishable from it, leaving no outward trace to indicate its presence in the fig. The larvæ are not injurious when eaten with the figs, the objection to them being the unsightly condition their work gives to the fruit. If figs are delivered to the packers promptly from the interior, i. e., within a week after being gathered, the majority of larvæ will be too small to be objectionable or even distinguishable at the time the figs are sterilized.

As attested by a number of the large fig packers in Smyrna, the installation of machinery adequate to sterilize the entire output of packed figs from a "khan" is quite possible. Packers are, moreover, willing to proceed immediately toward that end if sterilization of figs (or whatever term we choose to use for the process of killing the "worms") is insisted upon and imposed with equal rigidness upon all. So long, however, as some packers can find means of evading the trouble and expense of sterilizing, and are thus enabled to undersell those packers who are put to extra expense in improving their product, and are at the same time assured of being able to sell their figs—or are perhaps even given a preference by some American importers because of the lower price they quote—it is not likely that much advance will be made in the way of sterilization. These things alone keep many packers from investing on a large scale in improvements that would greatly benefit the trade. In order to progress they must have the protection of this Government.

Without such action as can be taken against the fig moth in the "khan," the insect will only with the greatest difficulty be eradicated or even greatly reduced in number in figs coming to this country. There are several species of parasitic enemies of the fig moth present in Asia Minor, and often as high as 40 to 50 per cent of the larvæ are destroyed by them; but, as in all similar cases of insect parasitism, the eradication of the host is accomplished after the worst of the damage has been done. The larvæ, until they are full grown and about to leave the figs to pupate, do not succumb to the attack of parasites. The combined activities of all the parasites prove to be of little service in relieving the "wormy" condition of figs, so we must depend exclusively upon artificial means.

SUMMARY OF PREVENTIVE MEASURES.

In summing up the measures which will prove most instrumental in the eradication of the fig moth, we find that they fall into two classes—those of prevention and those of destruction. In the first class there are four very important measures to be observed: (1) The rapid disposal or destruction of the June crop of figs; (2) the covering of the figs at night while on the "serghi"; (3) the screening of the fig "depots" in the interior; (4) the prompt delivery of the figs to the "khans" after they are gathered. These are all extremely difficult to enforce, especially in a country like Turkey, where superstition is the ruling law of the lower classes. Without special legislation on the part of the Turkish Government we can scarcely hope for any decided change, for some time to come, in the customs that now prevail. The last of these four measures of prevention—the prompt delivery of the figs to the packers—*should be insisted upon* in so far as possible. Since dependence must be placed upon destroying the larvæ in the figs, it is highly desirable that the larvæ be no older and larger than necessary when killed, if it is intended to save the appearance of the fruit.

Of the three methods mentioned for destroying the fig-moth larvæ in the "khans"—by steam, hot water, or dry heat—it remains for the packers to demonstrate by actual experience which is the more practical. Experimentation has shown that each method has its advantages, and each is capable of eradicating the larvæ under proper conditions. It would be well to determine the temperature and length of exposure necessary to kill the "worms," and leave to the option of the packer what method he may prefer. It must be emphatically understood that prompt and decisive action is necessary on the part of one or both of the Governments interested if any decided improvement is to be expected in the present methods of manipulation and packing of figs, of a character that will insure their freedom from larvæ.

O

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 105.
L. O. HOWARD, Entomologist and Chief of Bureau.

THE ROCKY MOUNTAIN SPOTTED FEVER TICK.

WITH SPECIAL REFERENCE TO THE PROBLEM OF ITS CONTROL IN THE BITTER ROOT VALLEY IN MONTANA.

BY

W. D. HUNTER,
In Charge of Southern Field Crop Insect Investigations,

AND

F. C. BISHOPP,
Entomological Assistant.

[In Cooperation with the Biological Survey and the Montana Agricultural College.]

ISSUED NOVEMBER 17, 1911.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1911.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 105.

L. O. HOWARD, Entomologist and Chief of Bureau.

THE ROCKY MOUNTAIN SPOTTED FEVER TICK.

WITH SPECIAL REFERENCE TO THE PROBLEM OF ITS CONTROL IN THE BITTER ROOT VALLEY IN MONTANA.

BY

W. D. HUNTER,

In Charge of Southern Field Crop Insect Investigations,

AND

F. C. BISHOPP,

Entomological Assistant.

[In Cooperation with the Biological Survey and the Montana Agricultural College.]

ISSUED NOVEMBER 17, 1911.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1911.

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, *Entomologist and Chief of Bureau.*
C. L. MARLATT, *Entomologist and Acting Chief in Absence of Chief.*
R. S. CLIFTON, *Executive Assistant.*
W. F. TASTET, *Chief Clerk.*

F. H. CHITTENDEN, *in charge of truck crop and stored product insect investigations.*
A. D. HOPKINS, *in charge of forest insect investigations.*
W. D. HUNTER, *in charge of southern field crop insect investigations.*
F. M. WEBSTER, *in charge of cereal and forage insect investigations.*
A. L. QUAINTANCE, *in charge of deciduous fruit insect investigations.*
E. F. PHILLIPS, *in charge of bee culture.*
D. M. ROGERS, *in charge of preventing spread of moths, field work.*
ROLLA P. CURRIE, *in charge of editorial work.*
MABEL COLCORD, *in charge of library.*

SOUTHERN FIELD CROP INSECT INVESTIGATIONS.

W. D. HUNTER, *in charge.*

F. C. BISHOPP, H. P. WOOD, W. V. KING, G. N. WOLCOTT, *engaged in tick investigations.*
W. D. PIERCE, J. D. MITCHELL, E. S. TUCKER, T. E. HOLLOWAY, G. D. SMITH, E. A. MCGREGOR, HARRY PINKUS, W. A. THOMAS, THOMAS LUCAS, *engaged in cotton-boll weevil investigations.*
A. C. MORGAN, G. A. RUNNER, S. E. CRUMB, *engaged in tobacco insect investigations.*
T. C. BARBER, C. E. HOOD, *engaged in sugar cane and rice insect investigations.*
R. A. COOLEY, D. L. VAN DINE, WILMON NEWELL, A. F. CONRADI, C. C. KRUMBHAAR, *collaborators.*

LETTER OF TRANSMITTAL.

United States Department of Agriculture,
Bureau of Entomology,
Washington, D. C., July 20, 1911.

Sir: I have the honor to transmit herewith a manuscript entitled "The Rocky Mountain Spotted Fever Tick, with Special Reference to the Problem of its Control in the Bitter Root Valley in Montana," prepared by Messrs. W. D. Hunter and F. C. Bishopp, of this bureau.

The work of this bureau on the spotted-fever-tick problem began in 1909. It has been conducted in cooperation with the Biological Survey of this department and the Montana Agricultural Experiment Station. The investigation of the life history and habits of the tick which transmits spotted fever has revealed certain feasible and economical methods of control. These methods render it possible to reduce the numbers of the ticks to such an extent that the cases of spotted fever in the Bitter Root Valley will be very few in number, if, indeed, the disease is not eliminated altogether. The plans for this work are outlined in this manuscript.

It is recommended that the accompanying manuscript be published as Bulletin No. 105 of this bureau.

Respectfully,

L. O. Howard,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

	Page.
Introduction	7
Work upon which this bulletin is based	9
Possibility of increase of area of spotted fever	11
Importance of the control of the spotted-fever tick	14
Summary of facts bearing on importance of tick control	14
Distribution of the spotted-fever tick	15
Factors governing abundance	17
Summary of life history of the spotted-fever tick	19
The egg and larva	19
The nymph	19
The adult	19
Seasonal history and habits	21
The host animals of the spotted-fever tick	26
Other species of ticks found in regions where Rocky Mountain spotted fever occurs	31
Species of ticks which may play an important part in the dissemination of the disease should it be introduced into new regions	31
Practical control or eradication of the spotted-fever tick	32
Conditions favoring control	32
Importance of control throughout the Bitter Root Valley	36
Methods of destroying ticks	36
Dipping	37
Construction of vats	38
Handwork in the destruction of the spotted-fever tick	41
Definite recommendations for control or eradication of the spotted-fever tick in the Bitter Root Valley	41
Estimated cost of work	42
Supplementary means of control	43
Necessity for expert supervision	44
Bibliography of the more important writings on the spotted-fever tick	45

ILLUSTRATIONS.

PLATES.

Page.

PLATE I. Ticks and spotted fever in the Bitter Root Valley, Montana. Fig. 1.—View in Lo Lo Canyon, which leads into the Bitter Root Valley, showing conditions under which ticks thrive. Fig. 2.—Camp laboratory near Florence, Mont., in one of the most heavily infested localities known 8

II. The Rocky Mountain spotted-fever tick (*Dermacentor venustus*). Fig. 1.—Adult female unengorged, dorsal view. Fig. 2.—Adult male, dorsal view. Fig. 3.—Adult female unengorged, ventral view. Fig. 4.—Adult male, ventral view. Fig. 5.—Adult female in act of depositing eggs 20

III. Spotted-fever tick (*Dermacentor venustus*) and *Dermacentor albipictus*. Fig. 1.—Adult spotted-fever tick which has deposited eggs. Fig. 2.—Larva of spotted-fever tick. Fig. 3.—Engorged nymph of spotted-fever tick. Fig. 4.—Same, ventral view. Fig. 5.—Adult male of *Dermacentor albipictus*. Fig. 6.—Adult female of *Dermacentor albipictus*, unengorged 20

TEXT FIGURES.

FIG. 1. Map showing area in which the spotted-fever tick occurs 16

2. Diagram showing possible seasonal history of spotted-fever tick 27

3. Dipping vat 38

THE ROCKY MOUNTAIN SPOTTED-FEVER TICK, WITH SPECIAL REFERENCE TO THE PROBLEM OF ITS CONTROL IN THE BITTER ROOT VALLEY IN MONTANA.

INTRODUCTION.

For many years a disease of human beings, known as spotted fever, has been known to occur in certain localities in the Rocky Mountain region of the United States. In fact the evidence is rather conclusive that the disease existed before the settlement of the country by white men. At any rate old residents of the Bitter Root Valley in Montana have informed us that the first white settlers were warned by the Indians of the danger of contracting a very serious disease if they visited certain localities. From what has been learned in recent years it is evident that these dangerous localities are the very ones in which spotted fever is now most prevalent.

The States in which the disease occurs most frequently are Montana and Idaho. There is no doubt, however, that it occurs in at least portions of other States, such as Oregon, Washington, Nevada, Utah, Wyoming, and Colorado.

Definite work on the nature and method of transmission of spotted fever was not begun until 1902. In that year Drs. Wilson and Chowning announced the theory that the "wood tick" is the natural agency through which the malady is transmitted from one human being to another. This hypothesis was based upon three observations: First, that the majority of cases of spotted fever showed histories of tick bites; second, that the localities in which the disease was most frequently contracted were those where ticks were most abundant; and, third, that the season of spotted fever coincided with the period when the ticks were most frequently observed. Drs. Wilson and Chowning had no facilities for proving their hypothesis in a scientific manner, but such proof was soon obtained. According to the late Dr. H. T. Ricketts[1] the first experiments which resulted in proof of the transmission of spotted fever by the tick were conducted by Drs. McCalla and Brereton, of Boise, Idaho, in 1905. In these experiments a tick which was found attached to a spotted-fever patient was removed and allowed to bite a healthy person. In

[1] Fourth Biennial Report, Montana State Board of Health, p. 106.

eight days this person developed a typical case of spotted fever. The experiment was continued by allowing the same tick to bite a second person. In this case again a typical case of spotted fever resulted. The results of the important experiments of Drs. McCalla and Brereton were not published by them.

In 1906 Dr. H. T. Ricketts, then connected with the University of Chicago, began a series of investigations which must always be considered classic. Not being aware of the experiments of Drs. McCalla and Brereton, Dr. Ricketts started with the hypothesis of Drs. Wilson and Chowning. His first work was devoted to determining whether guinea pigs and rabbits are susceptible to the disease and consequently suitable for inoculation experiments. The original experiments with rabbits were somewhat inconclusive, but it was found that the injection of blood from a human being suffering with spotted fever invariably brought about the disease in guinea pigs. In fact in these animals the disease was found to run a course very similar to that in human beings. It was thus determined that guinea pigs were suitable subjects for experiments to determine whether ticks could transmit the disease. On August 4, 1906, Dr. Ricketts announced the results of the first experiment in the tick transmission of the disease. A small female tick was placed on a guinea pig which had been inoculated with the blood of a patient who died of spotted fever. The tick was allowed to feed on this inoculated guinea pig for two days. It was then removed and placed in a pill box for two days. At the end of that time it was allowed to attach to the base of the ear of another guinea pig which had not been inoculated with spotted fever. After three and one-half days the temperature of this guinea pig rose and remained above normal for more than seven days. The pig also showed practically all of the other symptoms of spotted fever. In fact, there was no doubt whatever that the guinea pig contracted spotted fever from the bite of the single tick. As a control on the experiment Dr. Ricketts placed two other guinea pigs in the cage occupied by the animal upon which the tick had been placed. They remained there for two weeks. These two pigs showed no indications whatever of fever. Thus the possibility of infection by contact or by feces was eliminated. The only difference between the conditions surrounding the pig which contracted fever and those surrounding the others was that the former was bitten by a fever tick.

During the following year (1907) Dr. Ricketts succeeded in transmitting the disease by ticks in a number of additional cases. In one experiment he found that the male tick as well as the female is capable of transmitting the disease. In other experiments it was determined that the larval or nymphal tick may acquire the disease and retain it through the molting period, and transmit the infection in the following stage to another host. The most interesting experi-

FIG. 1.—VIEW IN LO LO CANYON, WHICH LEADS INTO THE BITTER ROOT VALLEY, SHOWING CONDITIONS UNDER WHICH TICKS THRIVE.

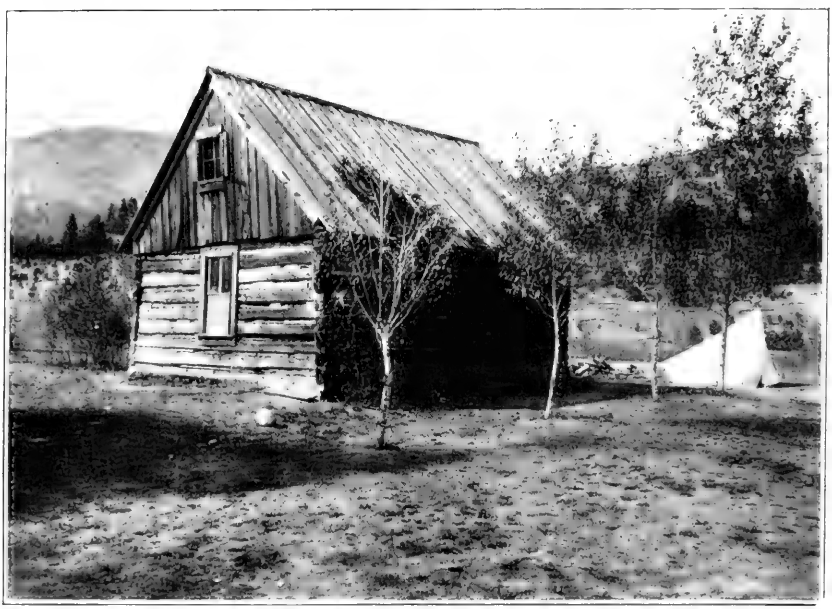


FIG. 2.—CAMP LABORATORY NEAR FLORENCE, MONT., IN ONE OF THE MOST HEAVILY TICK-INFESTED REGIONS KNOWN.

TICKS AND SPOTTED FEVER IN THE BITTER ROOT VALLEY, MONT.

ments, however, were with adult ticks. It was found that when an adult becomes infected with the disease, the infection passes through the eggs developed in the tick, so that the young of the next generation may transmit the disease.[1]

The main points determined by Dr. Ricketts are as follows:

(1) Guinea pigs and certain other animals, as monkeys, are susceptible to spotted fever.

(2) Larval ticks applied to an infected animal contract the infection and are able to transmit it to the following or nymphal stage.

(3) Nymphal ticks feeding upon infected animals acquire the power of transmitting the disease as adults.

(4) Adult ticks are able to acquire the disease by feeding upon an infected animal and to transmit it through the egg stage to the succeeding generation.

(5) Infective ticks are to be found in nature.

The transmission of disease organisms through the egg stage of ticks is known in a number of other instances. It is the case with the tick *Margaropus annulatus* Say, which transmits splenetic fever of cattle in the southern portion of the United States. The causative organism of splenetic fever has actually been found in the eggs of this tick. Dr. Ricketts recently made a tentative announcement of the finding of the spotted-fever organism in the eggs of *Dermacentor venustus* Banks. Future investigation will undoubtedly result in certainty regarding this point.

Some of the main points determined by Dr. Ricketts were corroborated about the same time by Dr. W. W. King, of the Public Health and Marine-Hospital Service, whose results were published in the Public Health Reports of July 27, 1906.

WORK UPON WHICH THIS BULLETIN IS BASED.

The work of the Bureau of Entomology on the spotted-fever tick began in 1908, when the investigation of the life history and habits of the species was undertaken. Plans were made for determining the distribution of the tick and for the exhaustive life-history investigations necessary in the formulation of plans of control. Following the plan for determining the distribution of the tick, two men were selected, one to travel through the southern Rocky Mountain region and the other through the northern. The late Mr. F. C. Pratt made investigations in New Mexico, Arizona, southern California, and Colorado. Mr. W. V. King, whose work as an agent of the bureau began July 1, 1909, made the investiga-

[1] The Rocky Mountain spotted-fever tick, like a number of other species, exists in four distinct stages, namely, egg, larva, nymph, and adult. The eggs are invariably deposited on the ground in large masses. The larvæ which emerge from the eggs are minute six-legged animals. After feeding upon a suitable host, they drop to the ground and molt, becoming nymphs. In this stage they have eight legs. The nymph waits until it can attach to a host, engorges blood, drops, molts its skin, and becomes adult.

tions in the northern Rocky Mountain region. He explored Wyoming, Idaho, portions of Utah, and Oregon and Washington. Prof. R. A. Cooley, of the Montana Agricultural College, consented to cooperate with the bureau by directing the work of Mr. King and by submitting specimens from many localities in Montana. During 1909, Mr. J. D. Mitchell, of the Bureau of Etomology, visited New Mexico, and succeeded in determining the southernmost locality in which the fever tick is at present known to occur.

The life-history work upon the tick was conducted at Dallas, Tex., by Messrs. H. P. Wood, G. N. Wolcott, and the junior author. This began early in 1909 and has continued without interruption.

In February, 1910, a conference was held in Washington, D. C., with Prof. R. A. Cooley and Dr. C. Hart Merriam, then Chief of the Biological Survey, for the purpose of formulating definite plans for the continuation of the work. It was agreed that the determination of the range of the tick should be continued by correspondence rather than by sending men into the field and that the local aspects of the problem in the Bitter Root Valley should be investigated by placing an agent there. The Bureau of Entomology provided the necessary funds and established a laboratory near Florence, Mont. (See Pl. I, fig. 2.) Prof. Cooley agreed to supervise the work in Montana, and was appointed a collaborator in the bureau on March 1, 1910. At the same time Mr. W. V. King was appointed to work under the direction of Prof. Cooley in the Bitter Root Valley. This plan of cooperation has continued down to the present time.

The results obtained have been due, to a large extent, to the energy and acumen of Prof. Cooley and to the high grade of Mr. King's work. But a special word must be said about Mr. King. Undeterred by the possibility of contracting spotted fever, he located on an abandoned farm in the most dangerous locality known. In the immediate vicinity a number of deaths from spotted fever had occurred within a short time. He remained there throughout the season of 1910, subject to the risk of contracting the fever on his daily trips into the field or from the ticks used in the experiments at the camp laboratory. His devotion to the investigation outweighed all considerations of personal safety. Great credit must also be given Mr. C. Birdseye and Mr. A. H. Howell, of the Biological Survey, for assuming the risk of residence at the laboratory during a portion of the season of 1910. Mr. Birdseye continued the investigation of the mammals of the valley in 1911.

In addition to the work in cooperation with the Montana Agricultural College, in 1910, the bureau undertook to obtain information regarding the exact extent of the area in which the spotted-fever tick occurs. By means of a system of circulars and the generous cooperation of many physicians and other persons throughout

the Rocky Mountain region, a very large amount of information was obtained. In fact the correspondents sent in altogether 1,400 lots of ticks, 850 of which were of the fever species. These represented 225 localities in California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

Very many of the ticks received during the course of this work were in immature stages. Unfortunately our present knowledge of ticks is not sufficient to enable us to determine the species to which immature forms belong. This necessitates very special care in rearing to maturity the immature forms received. This work was done at Dallas, Tex., and naturally involved a large amount of skilled attention.

The information now in hand regarding the spotted-fever tick was greatly increased through the cooperation of the Biological Survey of this department. In 1910 two agents of this survey, Messrs. A. H. Howell and C. Birdseye, were located at the camp laboratory of the Bureau of Entomology near Florence, Mont. These agents were engaged in the collection of wild mammals upon which one stage or another of the spotted-fever tick occurs. This work resulted in showing the relative importance of the different mammals found in the Bitter Root Valley and adjacent mountains as carriers of the spotted-fever tick. It also revealed many points having a bearing on the original source of the disease in nature and on other important matters. The Biological Survey has also studied carefully the possibility of the eradication or control of all the wild mammals which carry the fever ticks.

In September, 1910, Prof. H. A. Morgan, director of the Tennessee Experiment Station, consented to make a trip to the Bitter Root Valley and to advise the forces cooperating regarding the sufficiency of the data obtained and the feasibility of plans of eradication based thereon.

Of course the authors have made full use of the available literature on the investigations that have been conducted by other persons. Most useful have they found the first and second spotted-fever reports of Dr. H. T. Ricketts, published in the Fourth Biennial Report of the State Board of Health of Montana.

POSSIBILITY OF INCREASE OF AREA OF SPOTTED FEVER.

The approximate area in which spotted fever occurs has been indicated in a previous paragraph. Since it has been shown, however, that a certain tick (*Dermacentor venustus* Banks) is the only known agent of transmission of the disease in nature, it follows that the possible area in which spotted fever may occur is at least coincident with the range of the tick, exactly as the possible range of yellow fever is as extensive as is the area in which the mosquito

which transmits it is to be found. Extensive work conducted by the Bureau of Entomology has shown with considerable accuracy the area in which spotted fever may be thus propagated. The map (fig. 1, p. 16) shows the area in which the necessary agent for transmission occurs, and consequently the possible geographical distribution of the disease. This map is based upon the examination of 850 lots of spotted-fever ticks received from 230 localities during the seasons of 1909, 1910, and 1911.

One of the most remarkable features of spotted fever is the fact that strains of different degrees of virulence exist in different localities. In Idaho the death rate is from 5 to 7 per cent. In the Bitter Root Valley in Montana, however, the death rate is about 70 per cent. One consideration which has caused the Bureau of Entomology to concentrate its efforts in the Bitter Root Valley is the possibility that the virulent form of the disease, now restricted to that valley, may eventually be carried into other regions where the presence of the tick would make transmission possible.

There are several ways by which the virulent strain of the disease might be carried out of the Bitter Root Valley. It could be taken either by ticks or in the blood of human beings. Carriage by ticks might occur when these animals are transported on men, horses, or cattle. Moreover, tick eggs or other stages of the tick which have been shown to contain the disease organism might be transported in hay or other commodities. There is also a chance that ticks in various stages might be transported on the hides of domestic or wild animals.

As regards carriage of infection in the blood of human beings, our conclusions are largely theoretical. It is not known how long the blood of a person who is attacked with spotted fever remains infective. It is probable, however, that it is infective for some days before the height of the fever and for some time thereafter. During the period either preceding or following the climax of the disease a person might leave the Bitter Root Valley. If in another locality he should be bitten by the fever tick and the specimen should escape, the establishment of the virulent form of the disease would be accomplished. In certain diseases similar to spotted fever, such as splenetic fever of cattle, the organism of the disease remains in the blood for many years without causing an acute or noticeable attack. Nevertheless, all ticks which feed upon these apparently immune animals become infected and can transmit the disease in acute form to other animals. Although nothing is known as to the persistency of the organism of spotted fever in the blood of persons who have apparently recovered, there is a possibility that it may remain for some months or even years. In this way there is a probability of

considerable extension of the territory in which the virulent form of the disease occurs, by migration out of the valley.

Naturally the chances of spread will increase with the development of the Bitter Root Valley and the growth of shipments of cattle or movements of people to other regions. These considerations are sufficient to justify very energetic means for control where the virulent form of the disease now occurs and where, as will be shown in this bulletin, the practical eradication of the tick, and, consequently, of spotted fever, is entirely feasible.

It has been shown by experiments conducted in the Institute of Infectious Diseases in Chicago that several species of ticks other than the form which occurs commonly in the Bitter Root Valley are capable of transmitting spotted fever. A very hopeful feature of the situation, however, is that in the valley there is but one tick species which attacks man. Therefore the other species are of no practical importance as regards spotted fever. Even among the species which feed upon the lower animals there are many thousands of specimens of *Dermacentor venustus* to every one of all other varieties. Moreover, means of control of this one species, such as will be described in this bulletin, will serve greatly to lessen the number of the other forms. For these reasons, in formulating plans for practical eradication it is necessary to consider only the one dominant tick in the valley.

There is one respect, however, in which the discovery that species other than *Dermacentor venustus* can transmit the disease may be of importance. The other forms occur over wide areas in the eastern and southern portions of the United States. It is conceivable that if the disease were once introduced in the blood of a human being or otherwise, the other ticks might propagate it and transmit it in regions far outside of the territory in which the fever is now known to occur. But the danger on this score is not so great as might be thought. In the first place, in no localities in the United States are any species of ticks as numerous as is the fever species in the Bitter Root Valley and elsewhere in the Rocky Mountain region. Consequently, the occurrence of anything like an epidemic of the disease would be impossible. Only occasional or rare cases could be expected. In the second place, it can not be foretold whether spotted fever would find general conditions suitable for propagation in localities outside of the Rocky Mountain region. Nevertheless the degree of danger from this source, while perhaps slight, emphasizes the importance of eradication of the spotted-fever tick in the mountain region and also of the discovery of effective means of control for all species of ticks wherever they occur.

IMPORTANCE OF THE CONTROL OF THE SPOTTED-FEVER TICK.

The most conspicuous loss from spotted fever is in human lives. In the Bitter Root Valley it was estimated in 1904 that 200 cases of the severe type of the disease had occurred up to that year. A conservative estimate of the mortality there, as has been stated, is 70 per cent. This means a loss of about 140 lives in this small valley. At the present time, with an increase in the population of the valley, it is estimated that about 20 cases of the disease occur annually. This means a loss of about 15 lives each year and this loss is certain to increase as the population of the valley becomes larger.

In Idaho it was estimated in 1908 by Dr. E. E. Maxey that the annual average of cases of spotted fever was 375. Undoubtedly, as Dr. Maxey pointed out, this estimate is very conservative. In all probability 500 would be a small estimate. The comparatively small mortality in Idaho would give a loss of human lives each year of about 35.

Taking into consideration the whole area over which spotted fever is more or less prevalent, it is conservative to estimate 750 cases each year with probably 75 deaths.

A great indirect injury the tick does in the Bitter Root Valley is in preventing the proper development of a region favored by a rich soil and by remarkable climatic advantages. As long as it is known that a dangerous disease exists there and that persons who farm or go into the country are especially subject to it, the valley can not prosper as it should. Relief from the tick would immediately result in increased land values and larger immigrations into the valley.

In a larger way the possibility of the spread of the virulent form of the disease outside of the valley must be considered. This alone would warrant a much larger expenditure than is actually required for extermination or control in the valley.

SUMMARY OF FACTS BEARING ON IMPORTANCE OF TICK CONTROL.

It has been proved beyond peradventure by the investigations of Dr. Ricketts and others that spotted fever is transmitted in nature only by certain ticks. In the region where the disease now occurs it is transmitted to man by a single species of tick. Therefore the rational method of eradicating the disease is to attack this tick. In this way the proper procedure is exactly analogous to that being followed in the eradication of splenetic fever of cattle from the United States, by the eradication of the tick which transmits it. In the case of splenetic fever, certain more or less effective means of combating the disease itself have been discovered. These are in the form of a method of preventive inoculation and the administration of certain

drugs. In spite of this it has been found that the only hope for the eradication of the disease, or even for practical control, is in the destruction of the ticks. Inasmuch as no means of preventing or curing spotted fever are known, the importance of attacking the ticks is much greater than in the case of splenetic fever. The situation is also analogous to that brought about by malaria and yellow fever, which, as is well known, are transmitted by certain mosquitoes. The control of these diseases in all parts of the world has practically resolved itself into a warfare against the mosquitoes.

These considerations seem to make it very evident that the logical course to follow in the eradication or control of spotted fever is the elimination of the tick. The problem becomes purely an entomological one. Under these circumstances, it is most fortunate that certain feasible and economical means of eradication, first outlined in a rather general way by Dr. Ricketts, have been placed upon an exact and certain basis by the recent investigations of the Bureau of Entomology.

DISTRIBUTION OF THE SPOTTED-FEVER TICK.

As is shown in the accompanying map (fig. 1) the range of the Rocky Mountain spotted-fever tick extends throughout the northern part of the Rocky Mountain region across the Great Basin to the eastern edge of the Cascade Range. The southernmost limit of the tick is in the northern edge of New Mexico. Although the distribution of the species in Canada has not been determined, there is little doubt that it extends over the southern half of British Columbia and the western portion of Alberta. However, only one accurate record of the occurrence of this species in Canada has been made, namely, by Dr. H. G. Dyar, who captured two female specimens at Kaslo, British Columbia, in 1903.

While infestation occurs throughout large portions of Montana, Idaho, Washington, Oregon, Nevada, Utah, Wyoming, and Colorado, comparatively small areas in New Mexico and California are infested. The tick probably occurs throughout the entire Black Hills region in South Dakota and Wyoming, although but one collection has been made in that region.

Naturally there is no uniformity in the abundance of the tick throughout the territory in which it occurs.

Our knowledge of the local occurrence of the tick throughout the Western States is not sufficiently complete to enable us to make definite statements as to areas within the whole infested region in which comparatively few ticks are to be found. We do know, however, that certain sections of the country which are unfavorable for the development of the species are only slightly or not at all infested.

During the investigation about 850 lots of the fever species have been collected. The following is a list of the counties and the number of localities within those counties where the species has been taken by the bureau:

FIG. 1.—Map showing region in the United States in which the Rocky Mountain spotted-fever tick occurs. The degree of shading indicates the relative abundance of the tick in different sections. (From Bishopp.)

NUMBER OF LOCALITIES, BY COUNTIES AND STATES, IN WHICH THE SPOTTED-FEVER TICK IS KNOWN TO OCCUR.

California.—Modoc County, 3; Lassen County, 1.

Colorado.—Boulder County, 4; Clear Creek County, 1; Eagle County, 1; Garfield County, 1; Gunnison County, 1; Jefferson County, 1; Lorimer County, 3; Mesa County, 2; Pitkin County, 1; Summit County, 1.

Idaho.—Bannock County, 7; Bingham County, 2; Blaine County, 3; Boise County, 1; Bonner County, 2; Canyon County, 1; Cassia County, 2; Elmore County, 3; Fremont County, 6; Kootenai County, 2; Lemhi County, 2; Lincoln County, 2; Oneida County, 4; Shoshone County, 1; Washington County, 1; Twin Falls County, 1.

Montana.—Beaver Head County, 3; Broadwater County, 2; Carbon County, 1; Custer County, 1; Flathead County, 4; Gallatin County, 5; Granite County, 5; Lewis and Clark County, 4; Lincoln County, 2; Madison County, 6; Meagher County, 3; Missoula County, 8; Park County, 2; Powell County, 3; Ravalli County, 7; Rosebud County, 4; Sanders County, 5; Silver Bow County, 1; Teton County, 2; Yellowstone County, 1.

Nevada.—Eureka County, 1; Humboldt County, 2; Lander County, 2; Lincoln County, 2; Nye County, 3.

New Mexico.—Rio Arriba County, 1; San Miguel County, 1.

Oregon.—Baker County, 1; Crook County, 3; Grant County, 1; Harney County, 3; Klamath County, 1; Lake County, 1; Malheur County, 2; Sherman County, 1; Umatilla County, 2; Union County, 1.

Utah.—Boxelder County, 2; Cache County, 2; Iron County, 1; Uinta County, 1; Utah County, 3; Wasatch County, 3.

Washington.—Asotin County, 2; Chelan County, 2; Douglas County, 1; Grant County, 1; Kittitas County, 1; Spokane County, 3; Stevens County, 14; Yakima County, 3.

Wyoming.—Albany County, 3; Bighorn County, 6; Carbon County, 3; Fremont County, 6; Latrona County, 3; Park County, 2; Uinta County, 2; Weston County, 1.

The above is far from being a complete list of those counties in which the spotted-fever tick occurs, yet it gives a definite idea of the territory infested. It should be understood that the number of localities given for a county does not represent the relative abundance of the tick in that county. The table includes only the number of localities from which the tick has actually been received. Greater population or a larger number of collectors in some counties has given more localities than in others, while the actual abundance of the tick may be exactly the reverse. Further investigation throughout the Rocky Mountain region will undoubtedly show the tick to be present in the majority of the counties included in the area shown to be infested in figure 1. Dr. E. E. Maxey[1] (1908, p. 4) reports that the tick has been found to occur in all of the counties of Idaho with the exception of Latah.

As is pointed out in Circular No. 136 of the Bureau of Entomology, the fever tick is known to occur at various elevations from slightly over 500 feet to nearly 9,000 feet above sea level. The species occurs in greatest abundance in the area known as the transition zone. It is also commonly found in the Canadian and Upper Sonoran life zones.

FACTORS INFLUENCING ABUNDANCE.

The occurrence and abundance of this tick within a given locality are dependent, to a large extent, upon the presence of favorable conditions for development. These conditions are, first, the existence of the small mammals which serve as hosts for the immature stages; second, the presence of large mammals upon which the adults may

[1] See Bibliography, p. 45.

engorge, and, third, the existence of a certain amount of protection for the development of the stages when not on hosts. As a rule the abundance of ticks is dependent upon the amount of vegetation. Lands upon which some fallen timber and undergrowth occurs are usually found to harbor ticks in abundance, provided the hosts—certain small mammals and domestic animals—are also present. In the Bitter Root Valley the areas in which more or less heavy second growth has followed the removal of the original timber have been found to be most heavily infested with ticks. These areas are locally known as "slashings." (See Pl. I, fig. 1.)

It has been determined that the direct rays of the sun during the summer have a markedly injurious effect upon the early stages of the tick. This fact may be utilized to some extent, as will be shown later, in the control of the species by clearing the land of timber and underbrush. In small experiments it has been found that when the seed ticks are exposed to the sun during very hot weather they immediately crawl down the grass to the surface of the soil to seek protection, and in the absence of an abundance of moisture death results in a very few days. The exposure of freshly deposited eggs to the sun at Dallas, Tex., has been found to cause them to shrivel and dry within less than a day's time.

The relative abundance of rain, especially during the spring months, in different years has a marked effect upon the number of ticks occurring in a given locality. This factor is of little importance in the natural control of the adult stage of the tick, but is a potent factor in the destruction of the eggs and immature stages, particularly after the latter have become engorged and dropped from the animal.

Several other natural means of control of minor importance are also operating to some extent to keep the species in check. In barn lots. chickens have been observed to destroy the females which drop to the ground after becoming filled with blood. Some wild birds are known to feed upon various species of ticks, and in one instance, at least, they have been observed to destroy the engorged females of the spotted-fever tick. Certain species of ants are also thought to be important enemies of the pest, particularly when the ticks are in the immature stages.

Owing to the fact that the Rocky Mountain spotted-fever tick is primarily a northern form, and therefore accustomed to severe cold, it is doubtful whether severe winters are of much importance in its destruction. This is particularly true where there is an abundance of protection provided by brush and litter on the ground.

SUMMARY OF LIFE HISTORY OF THE SPOTTED-FEVER TICK.

As is the case with nearly all species of ticks, this one passes through four distinct stages, namely, the egg, the larva or seed tick, the nymph, and the adult.

THE EGG AND LARVA.

The eggs (Pl. II, fig. 5) are small, ovoid, brownish objects, about one thirty-eighth of an inch long. These hatch into minute, light brown, active six-legged creatures known as larvæ or seed ticks. (Pl. III, fig. 2.) Before further development takes place it is necessary for these seed ticks to feed upon the blood of some animal. They usually attach to small mammals, such as ground squirrels, and become filled with blood in from 3 to 8 days. They then drop off the host and find a convenient protected place in which to continue their development. Before engorging the seed tick measures about one thirty-seventh of an inch in length, but during feeding the body is considerably distended, so that it measures about one-eighteenth of an inch in length by one thirty-first of an inch in width when engorgement is complete. The color of the larvæ when engorged is slate-gray. Activity is greatly reduced on account of the weight of the blood imbibed.

THE NYMPH.

After a resting period of from 6 to 21 days the skin is shed from the body of the engorged seed tick and an active eight-legged nymph appears. The extra pair of legs is gained during the resting stage. This character is sufficient to distinguish the nymphs from the preceding or larval stage. In this stage it is necessary for the young tick again to find a host and fill with blood. This feeding period requires from 3 to 9 days. When engorgement is complete (see Pl. III, figs. 3, 4), the nymphs measure about one-sixth of an inch in length, while before engorgement the length is usually about one-seventeenth of an inch. The engorged nymphs are bluish gray in color and not very active.

THE ADULT.

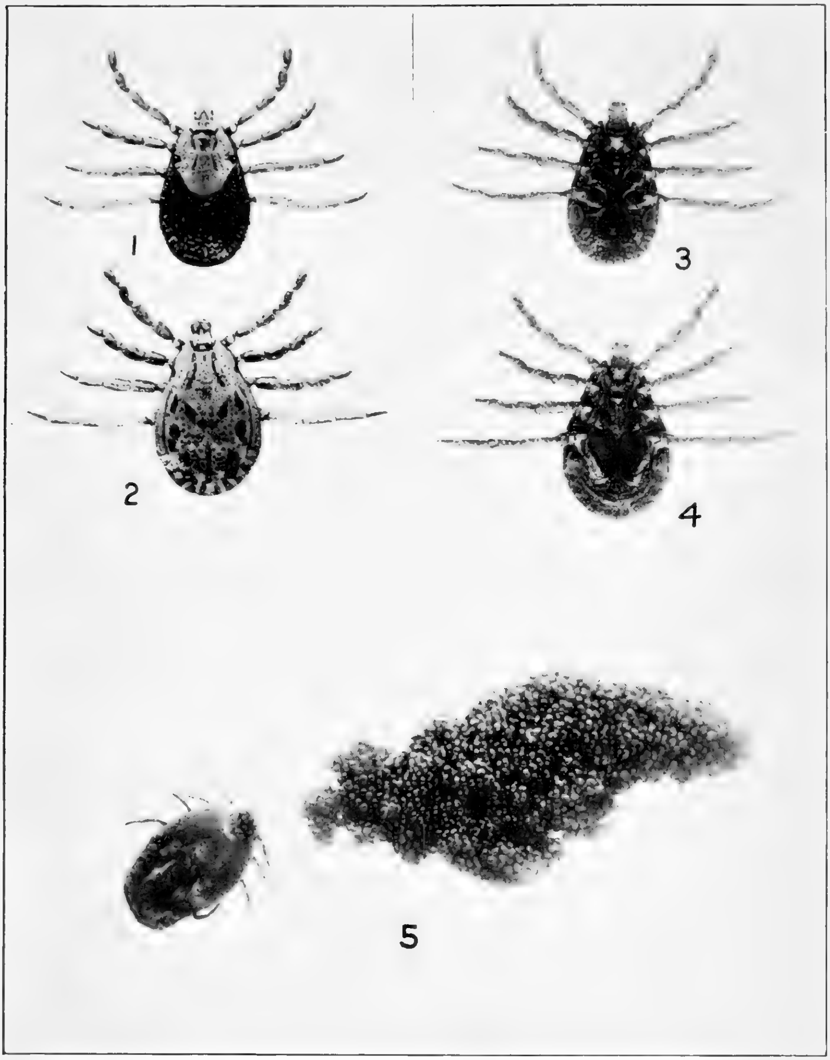
As in the case of the engorged larvæ, the nymphs, after dropping, seek a protected place in which to transform, and there become completely inactive. This resting stage requires a longer period than the preceding. During this time the sexual organs of the ticks develop. When the skins are shed the ticks appear as mature males and females. Shortly before the molting of the nymphs the light-colored shields on the back of the adult ticks can be seen through the thin skins which are soon to be shed. After the mature ticks escape from the nymphal skins they are rather soft and comparatively

inactive. They soon become dried out and the external structures become thoroughly hardened. The color pattern becomes more pronounced and activity increases. This is the stage in which the ticks are ordinarily observed in the spring months. The males (Pl. II, figs. 2, 4) and females (Pl. II, figs. 1, 3) are nearly the same size, but the former have a hard plate or shield covering the entire back. Upon this shield is a somewhat complicated pattern formed by white bands or stripes. In the female the shield is much smaller, covering only the anterior portion of the body. Almost its entire surface is covered with white. The portion of the body of the female behind the shield is rather soft and elastic. It is usually somewhat wrinkled and of a dark reddish-brown color. In this stage, as well as in the preceding, the ticks have eight legs, but the white markings on the backs of both sexes and the presence of a small genital opening on the underside near the "heads" of the ticks serve to distinguish them readily from the other stages. Of course the size of the adult ticks is considerably greater than that of either of the immature stages. Prior to feeding they usually measure about one-sixth of an inch in length by one-tenth of an inch in width.

Before reproduction can begin it is necessary for both the males and females to feed upon the blood of some animal. They usually attach to the large domestic animals, and after feeding about 4 days or more the males start in search of mates. Fertilization takes place on the host, and in from 8 to 14 days after attachment the females, having become filled with blood, drop from the host and seek a protected place in which to deposit their eggs. During the course of feeding the portion of the body of the female behind the shield is greatly distended, so that the specimens now measure about one-half inch long by one-third inch wide by one-fourth inch thick. On account of the enormous distention of the back part of the body of the female, the legs and head are rendered inconspicuous. A close examination, however, will show the white shield on the back just behind the "head." When the females are filled with blood the back part of the body is usually a bluish-gray color. Although the males imbibe a certain amount of blood when attached to an animal they never increase greatly in size as do the females.

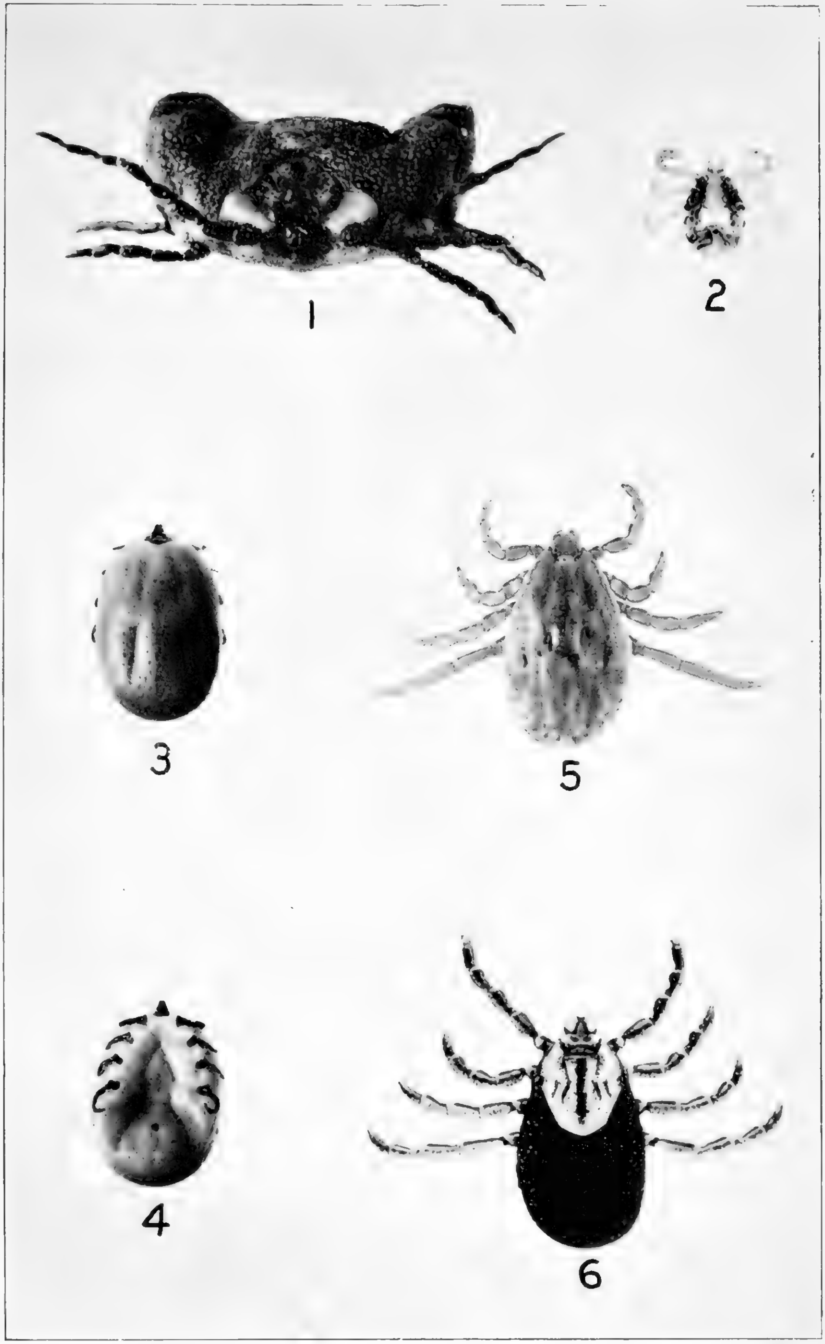
The females always drop from the host animal before beginning the deposition of eggs. Deposition continues for about 30 days, during which time several thousand eggs are deposited. (See Pl. II, fig. 5.) During the process of deposition the female gradually shrinks in size. When all of the eggs are expelled the tick is much shriveled (Pl. III, fig. 1) and has changed in color to a mottled yellowish. She dies within a few days after the last eggs are deposited.

While depositing her eggs the female remains in the same place, so that all of the eggs are in one large mass. The eggs hatch into seed ticks in from 16 to 51 days and the life cycle is again repeated.



THE ROCKY MOUNTAIN SPOTTED-FEVER TICK (DERMACENTOR VENUSTUS).

Fig. 1.—Adult female, unengorged, dorsal view. Fig. 2.—Adult male, dorsal view. Fig. 3.—Adult female, unengorged, ventral view. Fig. 4.—Adult male, ventral view. Fig. 5.—Adult female in act of depositing eggs. (Original.)



THE SPOTTED-FEVER TICK (DERMACENTOR VENUSTUS) AND DERMACENTOR ALBIPICTUS.

Fig. 1.—Adult spotted-fever tick which has deposited eggs. Fig. 2.—Larva of spotted-fever tick. Fig. 3.—Engorged nymph of spotted-fever tick. Fig. 4.—Same, ventral view. Fig. 5.—Adult male of *Dermacentor albipictus*. Fig. 6.—Adult female of *D. albipictus*, unengorged. (Original.)

SEASONAL HISTORY AND HABITS.

For convenience in tracing the life cycle of the Rocky Mountain spotted-fever tick we will begin with the appearance of the flat or unengorged females and males which appear with the first warm days of spring. It should be remembered that these ticks have remained dormant throughout the winter months. When they are rendered active during the warm spring days they are immediately ready to attach to an animal and engorge. Some of these ticks pass the winter in places where they are not readily reached by the warmth of the sun. Such specimens become active later than others. Emergence from winter quarters is therefore gradual, usually extending over a period of a few months, beginning about the 1st of March.

The time of the beginning of activity in the spring is also dependent to a considerable extent upon the relative earliness of the season and upon the locality. In lesser altitudes, and at the southern limit of the range of the species, activity may begin as early as the middle of February, while in the Bitter Root Valley it is probable that the ticks seldom become active in numbers before nearly the middle of March.

After leaving their winter quarters the adult ticks begin crawling about and usually ascend brush to await a host. They may crawl upon trees or other objects so as to get several feet above the ground.

In all ticks the anterior legs have well-developed sense organs located near their tips. These front legs are used as feelers. When the tick is disturbed it immediately begins to wave them in an endeavor to catch any passing object.

Having found a host, the ticks crawl about upon it until a suitable place for attachment is found. On cattle they are usually found in numbers on the dewlap, between the fore and hind legs, and along the belly. On horses they are commonly found between the legs and sometimes in the mane. They may, however, attach to any part of the host.

Attachment to the host is accomplished by means of a spiny beak, which has an opening in the end through which the blood of the animal is drawn. In from 4 to 8 days after attaching the males begin searching for mates. In order to fertilize the females they crawl beneath them, and after mating usually attach to the animal immediately under their mates. When the females have become one-half engorged the blood is rapidly imbibed, and complete engorgement is reached in a very short time, after which they loosen their hold and drop to the ground. Table I shows the time required for the engorgement of females on different hosts and during different times of the year.

TABLE I.—*Time required for engorgement of females of Dermacentor venustus at Dallas, Tex.*

Adults attached.		Dates of dropping as engorged females.		Period of engorgement.
Date.	Host.	First.	Last.	
				Days.
May 15, 1908	Ox	May 23	June 1	8-17
Mar. 19, 1910	Guinea pig	Mar. 28	Mar. 28	9
Apr. 1, 1910	Ox	Apr. 12	Apr. 13	11-12
May 4, 1910	Ox	May 12	May 17	8-13
Mar. 29, 1911	Ox	Apr. 7	Apr. 12	9-14
May 29, 1911[1]	Goat	June 3	June 15	5-17

[1] The specimens in this lot were fertilized and slightly engorged when applied.

After the dropping of the females the males usually remain on the host for some time. We have found that they crawl about over the animal, reattaching in different places and fertilizing a number of different females after one infestation of females has become engorged and dropped from the host.

Immediately after leaving the host engorged females endeavor to find some protected place in which to deposit their eggs. As has been stated, deposition may begin as soon as the seventh day after dropping, and all of the eggs, which usually number about 4,000, are deposited within 30 days. During the process of egg laying the female gradually shrinks in size and death takes place within a few days after all of the eggs have been laid. The length of time before the beginning of egg laying depends largely upon the temperature. During cool weather a period of 41 days has been known to pass after dropping before the first eggs were deposited.

The development of the seed tick begins within the egg as soon as it is deposited. After the embryonic tick has grown for about two weeks, a small white spot appears on one side of the egg. The appearance of this spot enables one to determine whether the eggs will hatch. The time required for incubation is largely dependent upon temperature conditions. In the Bitter Root Valley Mr. W. V. King has determined that this period ranges from 34 to 51 days, the longer period occurring in the early spring months. At Dallas, Tex., we have observed eggs to hatch as early as 15 days after they were deposited, the longest incubation period observed in that locality being 41 days. After the small seed ticks hatch from the eggs they usually remain clustered upon the eggshells for a few days and then crawl upon any object in their immediate vicinity to await a host. In this stage also the front legs are used as feelers, and when an animal comes into contact with the seed ticks, these immediately catch hold. Naturally during the larval stage, as well as during the adult stage, large numbers of the ticks starve before finding a suitable host upon which to engorge. The larvæ die much sooner from starvation than do the other stages of the tick.

During the summer months we have found that all of the seed ticks hatching from a mass of eggs usually die within one month after the first eggs hatch. In one instance a period of 117 days elapsed between the beginning of hatching of the eggs and the death of the last seed tick. This is the greatest longevity which we have observed.

Table II indicates the variations in the time required for the beginning of egg laying, incubation of the eggs, and length of time required for the starvation of the seed ticks:

TABLE II.—*Time required for beginning of deposition of eggs, hatching, and starvation of seed ticks of Dermacentor venustus.*

Date engorged female dropped or was picked from host.	Date first eggs were deposited	Period from dropping of female to beginning of deposition.	Date hatching of eggs began.	Period from beginning of deposition to beginning of hatching.	Date all seed ticks were dead.	Period from beginning of hatching to death of last seed tick.	Mean daily temperature during incubation.
		Days.		*Days.*		*Days.*	*°F.*
June 11, 1909	June 27, 1909	16	July 15, 1909	18	Sept. 5	52	91.8
Mar. 28, 1910	Apr. 7, 1910	10	May 10, 1910	33	July 25	76	70.49
Apr. 2, 1910[1]	May 13, 1910	41	July 3, 1910	51	Aug. 1	30	....
Apr. 7, 1910	Apr. 17, 1910	10	May 19, 1910	32	July 19	61	74.6
Apr. 13, 1910	Apr. 20, 1910	7	May 25, 1910	35	Aug. 15	82	71.78
Apr. 26, 1910	May 2, 1910	6	May 31, 1910	29	July 30	60	71.63
May 1, 1910[1]	May 19, 1910	18	July 9, 1910	51	Sept. 3	56	....
May 14, 1910	May 23, 1910	9	June 12, 1910	20	Aug. 31	80	79.64
May — 1910[1]	.....do.......	....	July 9, 1910	47	Nov. 3	117	....
June 4, 1910	June 13, 1910	9	June 29, 1910	16	Sept. 29	92	84.37
June 4, 1910[1]	June 17, 1910	13	July 21, 1910	34	Aug. 11	21	....
July 16, 1910	July 25, 1910	9	Before Aug. 10, 1910	16	Sept. 30	51	84.59

[1] These records were made in the Bitter Root Valley in Montana; all others were made at Dallas, Tex.

Those larvæ which succeed in finding an animal upon which to engorge usually attach about the head and ears of the host, become filled with blood, and drop from the animal between the third and eighth days. In nature the larvæ feed almost entirely upon the small wild mammals, although experimentally they have been forced to engorge upon cattle. As has been stated, the larvæ after becoming engorged drop from the animal, find a protected place, shed their skins, and become active eight-legged creatures known as nymphs. These nymphs emerge from the quiescent seed-tick stage from about the middle of July to the beginning of cold weather. Some of those transforming during the summer find hosts, become engorged, and drop for molting. A few of these probably molt to adults before cold weather begins and hibernation takes place in the adult stage. These few individuals are the only ones which complete their life cycle in a single season. It should be emphasized that these nymphs, as well as the seed ticks, feed almost exclusively on small wild mammals. Tables III and IV show the length of the engorgement and molting periods of larvæ and nymphs.

TABLE III.—*Time required for molting of seed ticks and nymphs of Dermacentor venustus.*

Seed ticks dropped engorged.		Date seed ticks molted.		Period from dropping to molting.	Nymphs dropped engorged.		Date nymphs molted.		Period from dropping to molting.
Date.	Number.	First.	Last.		Date.	Number.	First.	Last.	
1908. Apr. 5	23	1908. Apr. 20	1908. Apr. 24	*Days.* 15–19	1908. Aug. 6	17	1908. Aug. 20	1908. Aug. 22	*Days.* 14–16
May 17	15	May 27	May 30	10–13	1909. Sept. 15	5	1909. Aug. 6	1909. Aug. 7	21–22
1909. Aug. 6	7	1909. Aug. 13	1909. Aug. 16	7–10	Oct. 3	3	Oct. 21	1910. Mar. 22	18–170
Sept. 1	56	Sept. 7	Sept. 10	6–9	1910. Mar. 23	2	1910. May 4	May 23	42–61
1910. July 4[1]	Many.	1910. July 18	1910. July 25	14–21	Apr. 14	13	May 24	May 30	40–46
July 8[1]	Many.	July 19	...do.....	11–17	July 21	1	Aug. 1	Aug. 1	11
July 22[1]	Many.	Aug. 8	Aug. 11	17–20	Aug. 1	6	Aug. 14	Aug. 16	13–15
1911. May 22	110	1911. May 30	1911. June 2	8–11	Aug. 19	12	Aug. 31	Sept. 4	12–16

[1] These records were made in the Bitter Root Valley, Mont.; all others were made at Dallas, Tex.

TABLE IV.—*Time required for engorgement of seed ticks and nymphs of Dermacentor venustus.*

Seed ticks applied.		Date of dropping as engorged seed ticks.		Period of engorgement.	Nymphs applied.		Date of dropping as engorged nymphs.		Period of engorgement.
Date.	Host.	First.	Last.		Date.	Host.	First.	Last.	
1908. Apr. 2	Ox.........	1908. Apr. 5	1908. Apr. 10	*Days.* 3–8	1908. Apr. 1	Ox.........	1908. Apr. 5	1908. Apr. 8	*Days.* 4–7
July 12	.....do.....	July 15	July 18	3–6	1909. Aug. 13	Guinea pig.	1909. Aug. 17	1909. Aug. 18	4–5
1909. July 28	Guinea pig.	1909. Aug. 2	1909. Aug. 4	5–7	Sept. 10	Rabbit.....	Sept. 14	Sept. 15	4–5
Aug. 2	Rabbit.....	Aug. 7	Aug. 7	5	1910. May 24	Bovine.....	1910. May 30	1910. May 30	6
Aug. 27	Guinea pig.	Aug. 29	Sept. 3	2–7	Aug. 13	Rabbit.....	Aug. 18	Aug. 20	5–7
1910. July 19[1]	Ground squirrel.	1910. July 22	1910. July 23	3–4	Aug. 19	Rabbit.....	Aug. 23	Aug. 28	4–9
1911. May 18	Guinea pig.	1911. May 21	1911. May 24	3–6	Aug. 17[2]	Ground squirrel.	Aug. 22	Aug. 27	5–9

[1] This record was made by W. V. King in the Bitter Root Valley, Mont. Dropping probably began on July 21, or the second day after application.
[2] This record was made in the Bitter Root Valley, Mont. Records not referred to in footnotes were made at Dallas, Tex.

Those larvæ which hatch from eggs deposited by females which do not find hosts until late in the spring become engorged during July and August and do not molt to nymphs until shortly before winter. It is thus necessary for the nymphs which appear late in the summer to pass the winter in that stage. These nymphs appear in the spring shortly after the emergence of the adult ticks; that is, shortly after the middle of March. They continue to emerge from

their winter quarters for some time, the last individuals not securing hosts upon which to engorge until early in July. These individuals molt to adults during the latter part of the summer, and the resulting adults pass the winter before feeding.

In contrast to the short length of life as exhibited by the larvæ, we find the vitality of the nymphs and adults to be remarkably great. It has been determined that adults collected on vegetation during the spring months may survive for a period of 413 days without food. These individuals undoubtedly passed the winter in the adult stage, and therefore the total length of life must have been approximately one and two-thirds years. However, in nature the great majority of the ticks with a vitality equal to this lot would probably find hosts and become engorged. Unfed nymphs have been found to survive a period of more than 300 days. It is thus possible for ticks which pass the winter in the nymphal stage to live until at least July 15 of the following year. Under natural conditions this longevity is probably even greater.

The following is a summary of the life cycle of the tick: The winter is passed as flat or unengorged males and females and as unengorged nymphs. The former are present from about March 15 to July 15, during which time they find hosts and become engorged. It is during this period that the pest attacks man and communicates to him the germs of Rocky Mountain spotted fever. The eggs deposited by the females which find hosts early in the spring hatch into larvæ, which may develop into adults by the first or middle of September. The offspring of the females which become engorged late in the season succeed in developing only as far as the unengorged nymphal stage before cold weather begins. The overwintered nymphs begin appearing from their winter quarters during the latter part of March. They are to be found upon small wild mammals from that time until about the middle of July, at which time the nymphs which have developed from the females engorged during that spring are also present. Overwintered nymphs transform to adults during the summer and fall, and the majority of these adults pass the winter in the unfed condition. A few of the first nymphs to find hosts early in the spring may molt to adults sufficiently early in the summer to allow the adults to become engorged, deposit eggs, and the transformation to proceed to the unfed nymphal stage by the approach of cold weather, thus completing a life cycle in one year. However, the individuals which proceed with development beyond the unengorged adult stage during the same season must be very exceptional. When the mean temperature is low during the spring and early summer it is almost certain that none of the individuals which have passed the winter as unengorged nymphs develop further than unengorged adults during that season.

It has been observed that even though the adults which transform from overwintered nymphs are kept confined with the host animal during the summer or fall following their maturity, they show no marked desire to feed, usually endeavoring to crawl away and become quiet. Thus the habit of the adults of attaching to hosts in the spring appears to be so well established that they can scarcely be induced to attach to a host after midsummer.

From the foregoing statements it is evident that although a few of the ticks may complete their life cycle—that is, the transformation from unengorged adults to unengorged adults of the next generation, or from unengorged nymphs to unengorged nymphs of the next generation—during one season, the majority require two years for this cycle. Should overwintered nymphs not find hosts until late in the season and thus not become adult until the approach of winter, the resulting adults, if unable to find hosts, may survive until the second spring following. Ticks which pass the winter in the adult stage may survive until the second spring following, then engorge and produce offspring which develop to nymphs the second summer, pass the winter in the nymphal stage, and complete development to unengorged adults during the third season. Thus it is apparent that under certain conditions three years might be required for the completion of the life cycle. This would necessitate the destruction of the adult ticks during three successive seasons in order to eradicate the species.

Figure 2 shows several of the ways in which development may proceed.

THE HOST ANIMALS OF THE SPOTTED-FEVER TICK.

The investigations conducted by Dr. Ricketts indicated that the Rocky Mountain spotted fever tick is restricted in regard to its host relations. Our investigation has shown that this restriction of certain stages of the tick to certain classes of animals is very well marked. *The examination during three seasons of nearly 800 wild mammals which are inhabitants of the Bitter Root Valley and numerous observations made elsewhere have shown that, with few exceptions, only the immature stages of the tick are to be found on this class of hosts. On the other hand, the large domestic animals are the principal hosts of the adult ticks, and the immature stages are rarely, if ever, found upon them.* This restriction of the adult stage to the larger mammals, now a firmly fixed habit of the tick, undoubtedly arose from the fact that the adult ticks are so large that they can be easily removed by the smaller mammals. As will be pointed out in the discussion of remedial measures, this habit of the Rocky Mountain spotted-fever tick may be taken advantage of in the control or eradication of the species.

FIG. 2.—*Diagram showing the possible seasonal history of the Rocky Mountain spotted-fever tick.*

Overwintered individuals.	Unengorged adults.	Some fail to engorge the following season.	But engorge and deposit eggs the second spring.	These develop to unengorged nymphs that season and pass the winter in that stage.	These engorge and molt to adults the following summer.	These require three years, to complete the life cycle.
		Some become engorged early in spring.	Eggs deposited by these hatch in early summer.	Some seed ticks engorge and molt to nymphs in midsummer.	A few of these nymphs may engorge and molt to adults in the fall. These pass the winter as unengorged adults.	These require but one year to complete the life cycle from unengorged adults to unengorged adults.
					The majority do not feed but pass the winter as unengorged nymphs.	These engorge and molt the following spring, thus requiring two years to complete the life cycle.
				Others engorge and molt to nymphs in late summer.	These pass the winter as unengorged nymphs.	
		Others become engorged in late spring and early summer.	Eggs deposited by these hatch in mid or late summer.	Some seed ticks engorge and molt to nymphs in late summer or early fall.	These pass the winter as unengorged nymphs or a few may engorge and pass the winter as engorged nymphs.	
				A very few remain unengorged or engorge in the fall.	These enter the winter as unengorged or engorged larvæ and die during the winter.	
	Unengorged nymphs.	Some become engorged in spring.	These molt to adults in spring or early summer.	A few may engorge in summer and deposit eggs.	A few of the earlier hatch and the larvæ engorge and molt to nymphs which pass the winter in this stage.	These complete the life cycle from unengorged nymph to unengorged nymph in one year.
					The later-deposited eggs either fail to hatch or die during winter as seed ticks.	
		Others become engorged in summer.	These molt to adults in late summer or fall.	Remain quiet during the rest of the summer.	And pass the winter as unengorged adults.	Some of these engorge, deposit eggs, and the resulting seed ticks transform to nymphs the following year, thus requiring two years to complete the life cycle. Others fail to find hosts and do not engorge until the second spring, development proceeding that season to unengorged nymphs, thus requiring three years to complete the life cycle.

Among the domestic animals which act as hosts for the adult stage of the tick, horses and cattle are of prime importance. A number of collections indicates that sheep are frequently attacked, but with smaller numbers of ticks. Dogs have also been found to harbor this species, but in limited numbers only. Among nearly 100 collections of ticks made on dogs in the territory in which this species occurs only 12 lots of this tick have been obtained. Only 2 of these 12 lots contained females which were sufficiently engorged to deposit eggs. This indicates that the majority of the ticks are scratched off by the dogs before becoming fully filled with blood. Mules and asses have also been found infested with this species, and in two instances collections have been made upon hogs. It is not likely that the latter host is of much importance, particularly when the animals are kept confined in pens and thus not exposed to the ticks.

Among the wild animals which act as hosts for the adults, the mountain goat harbors by far the greatest number. In addition to specimens of the adults, nymphs have also been found upon them. The brown bear and coyote have been found to be infested with considerable numbers of spotted-fever ticks, some of the specimens being sufficiently engorged to deposit eggs. The snowshoe rabbit and jack rabbit have occasionally been observed to be infested with limited numbers of adults, but on neither of these hosts have engorged specimens been captured. The woodchuck has also been found to act as a host for the adult stage. In only one instance, however, were specimens taken upon this host, although 51 of the animals were examined during the investigation.

The Columbian ground squirrel is undoubtedly by far the most important host of the immature stages of this tick in the Bitter Root Valley. In other parts of the Western States, where this species of ground squirrel does not occur, related species have been found to act as hosts for both of the immature stages of this tick. In the Bitter Root Valley 65 per cent of the 341 Columbian ground squirrels examined were found to be infested with immature ticks of the genus Dermacentor. Owing to the fact that very large numbers of the immature stages of ticks belonging to the genus Dermacentor collected in the Bitter Root Valley were reared to adult and all found to be the Rocky Mountain spotted-fever tick, we can say with practical certainty that this is the only species of this genus which occurs on the small mammals in that locality. Second in importance as a host of the immature stages of this tick in the Bitter Root Valley is the yellow-bellied chipmunk. Thirty-seven per cent of 131 of these mammals which were examined were found to be infested with seed ticks and nymphs. The pine squirrel is also of much importance, as 29 per cent of the 181 mammals examined were in-

TABLE V.—*Wild mammals examined in the Bitter Root Valley during 1910–11, with number and stages of Dermacentor venustus found thereon.*

Common names.	Scientific names.	Number of animals examined.	Number of animals with spotted-fever ticks.	Per cent of animals examined which were infested with spotted-fever ticks.	Number of spotted-fever ticks found. Seed ticks.	Nymphs.	Adults.	Total.	Per animal.	State of engorgement of adult females.
Columbian ground squirrel	Citellus columbianus	341	240	64.5	841	1,234	0	2,075	6.09	
Yellow-bellied chipmunk	Eutamias b. luteiventris	131	49	37.4	539	60	0	599	4.57	
Pine squirrel	Sciurus h. richardsoni	181	53	29.3	503+	83	0	586+	3.24	
Woodchuck	Marmota flaviventer	47	26	55.3	9	379	2 or 3	390	8.29	Slight.
Side-striped ground squirrel	Callospermophilus l. cinerascens.	48	25	52.1	31	100	0	131	2.72	
Wood rat	Neotoma cinerea	16	11	68.8	8	12	0	20	1.25	
Snowshoe rabbit	Lepus bairdi	4	3	75.0	0	3	[1] 3	6	1.50	One-seventh.
Cottontail rabbit	Sylvilagus nuttalli	16	5	31.3	11	4	0	15	.94	
White-footed mouse	Peromyscus m. artemisiæ	50	[2] 6	12.0	16	4	0	20	.40	
White-bellied chipmunk	Eutamias q. umbrinus	58	5	8.6	44	4	0	48	.83	
Large meadow mouse	Microtus modestus	32	[2] 6	18.8	0	7	0	7	.22	
Jumping mouse	Zapus princeps	13	[2] 1	7.7	1	0	0	1	.08	
Pika or rock rabbit	Ochotona princeps	28	1	3.6	0	1	0	1	.04	
Pocket gopher	Thomomys fuscus	12	1	8.3	1	0	0	1	.08	
Longtailed meadow mouse	Microtus mordax	5	[2] 0	0	0	0	0	0	0	
Gray meadow mouse	Microtus n. canescens	2	[2] 0	0	0	0	0	0	0	
Red-backed mouse	Evotomys idahoensis	4	[2] 0	0	0	0	0	0	0	
Flying squirrel	Sciuropterus alpinus	3	0	0	0	0	0	0	0	
Shrews	Sorex sp.	10	[2] 0	0	0	0	0	0	0	
Mountain goat	Oreamnos montanus	3	3	100.0	0	(3)	300+	300+	100.0+	Unengorged to fully engorged.
Brown bear	Ursus americanus	1	1	100.0	0	0	[4] 13	13	13.0	Slightly to one-fourth.
Coyote	Canis lestes	2	2	100.0	0	0	[5] 33	33	16.5	Unengorged to slightly.
Mule deer	Odocoileus hemionus	6	0	0	0	0	0	0	0	
White-tailed deer	Odocoileus leucurus	2	0	0	0	0	0	0	0	
Elk	Cervus canadensis	1	0	0	0	0	0	0	0	
Badger	Taxidea taxus	3	1	33.3	0	0	[6] 1	1	.3	
Weasel	Putorius arizonensis	5	0	0	0	0	0	0	0	
Muskrat	Fiber zibethicus	3	0	0	0	0	0	0	0	
Bats	Vespertilionidæ	7	0	0	0	0	0	0	0	

[1] 2 males, 1 female.
[2] Several dead before being examined. Some ticks may have left the animals.
[3] A few. These may have been nymphs of D. albipictus. They were lost before being examined.
[4] 4 males, 9 females.
[5] 15 males, 18 females. A few others escaped.
[6] 1 male (dead).

fested. Among the other mammals which are of considerable importance as hosts of the immature stages are the large chipmunk, the woodchuck, snowshoe rabbit, rock squirrel, wood rat, white-footed mouse, and meadow mouse.

Our knowledge of the tick hosts in the valley was greatly increased by the cooperation of the Biological Survey of this department. Messrs. Howell and Birdseye, of the Survey, were located at the camp laboratory and made extensive collections during 1910. This work was continued in 1911 by Mr. Birdseye. Table V furnishes a list of the wild mammal hosts of this tick. It includes all the records of the Biological Survey,[1] as well as a number made independently by Mr. King, of the Bureau of Entomology. The mammals are listed in the table according to their relative importance as hosts of the immature stages. It is especially worthy of note that among the wild mammals which act as hosts for the adult stage the mountain goat and brown bear are the only ones which were found to have ticks upon them which were engorged sufficiently to deposit eggs.

One hundred specimens of the birds commonly found in the valley were examined and found to be free from ticks.

TABLE VI.—*Host animals on which Dermacentor venustus in the adult stage has been found.*

ON DOMESTIC ANIMALS AND MAN.

Common names.	Scientific names.	Approximate number of hosts examined.	Approximate number of ticks collected.			State of engorgement of females.
			Males.	Females.	Total.	
Ox	Bos taurus	200	2,000	2,000	4,000	Unengorged to fully.
Horse	Equus caballus	800	2,500	2,500	5,000	Do.
Ass	Equus asinus	5	9	5	14	Do.
Mule	Equus asinus×caballus.	9	14	17	31	Do.
Sheep	Ovis airies	75	22	32	54	Unengorged to one-half.
Dog	Canis familiaris	100	18	20	38	Unengorged to three-fourths.
Goat	Capra hircus	5	0	4	4	Unengorged to slightly.
Hog	Sus scrofa	10	2	4	6	Unengorged to one-third.
Man	Homo sapiens	900	400	400	800	Unengorged to one-fourth.
Domestic cat	Felis domesticus	1	1	0	1	Unattached.

ON WILD ANIMALS.

Common names.	Scientific names.	Approximate number of hosts examined.	Males.	Females.	Total.	State of engorgement of females.
Mountain goat	Oreamnos montanus.	3	150	150	300	Unengorged to fully.
Coyote	Canis lestes	1	15	16	31	Unengorged to slightly.
Brown bear	Ursus americanus	1	4	9	13	Slightly to one-fourth.
Jackrabbit	Lepus sp	15	3	6	9	Slightly to one-sixth.
Woodchuck	Marmota flaviventer.	51	2 or 3	2 or 3	5	Slightly.
Snowshoe rabbit	Lepus bairdi	4	2	1	3	One-seventh engorged.
Wild cat	Lynx uinta	1	1	0	1	
Badger	Taxidea taxus	4	[2] 1	0	1	

[1] See United States Department of Agriculture, Biological Survey, Cir. No. 82.
[2] Dead.

OTHER SPECIES OF TICKS FOUND IN REGIONS WHERE ROCKY MOUNTAIN SPOTTED FEVER OCCURS.

Five species of ticks other than *Dermacentor venustus* have been found to occur more or less commonly in the Bitter Root Valley of Montana. These are: *Dermacentor albipictus* Pack. (Pl. III, figs. 5, 6), *Ixodes angustus* Neum., *Ixodes texanus* Banks, *Ixodes kingi* Bishopp, and *Haemaphysalis leporis-palustris* Pack. On account of the host relations of these ticks it is impossible for them to play any important part in the dissemination of Rocky Mountain spotted fever. *Dermacentor albipictus* has been found to occur on practically no other animals than horses, cattle, and mountain goats. It never attacks man. Neither one of the three species of Ixodes has been found to occur on man, and they very seldom attack the domestic animals, being confined to certain of the small wild mammals. The last-named species confines its attack exclusively to rabbits with the exception of the immature stages, which are occasionally found upon birds.

In parts of Idaho, Oregon, Nevada, and Utah, the rabbit Dermacentor (*Dermacentor parumapertus marginatus* Banks) is found quite commonly. Like the other common rabbit tick this species confines its attack exclusively to that host.

SPECIES OF TICKS WHICH MIGHT PLAY AN IMPORTANT PART IN THE DISSEMINATION OF THE DISEASE SHOULD IT BE INTRODUCED INTO NEW REGIONS.

Since it has been shown by Dr. Maver, of the University of Chicago, that Rocky Mountain spotted fever may be transmitted by several different species of ticks, the importance of limiting the disease-infested area to the territory now covered is strongly emphasized.

A closely related species, namely, *Dermacentor occidentalis* Neum., has been found to occur throughout western California and southwestern Oregon. At present the range of this species does not overlap that of the Rocky Mountain spotted-fever tick. On account of the fact that this species is an important pest of man, should the disease become introduced into the territory where it occurs its dissemination would be certain. In the eastern and southern United States several species occur which commonly attack man. Nearly all of these have host relations very similar to that of the Rocky Mountain spotted-fever tick, and therefore the disease might readily be transmitted from animal to animal and from animal to man by any of these species. The following species would probably be of principal importance in the Southern and Eastern States: The lone-star tick (*Amblyomma americanum* L.); the American dog tick (*Dermacentor variabilis* Say), and the gulf-coast tick (*Amblyomma maculatum* Koch). In the extreme southern portions of

Texas and New Mexico the Cayenne tick (*Amblyomma cajennense* Fab.), is a common pest of man.

PRACTICAL CONTROL OR ERADICATION OF THE SPOTTED-FEVER TICK.

In 1909 Dr. Ricketts suggested, in a general way, a plan for the practical eradication of spotted fever from the Bitter Root Valley by a campaign against the ticks. It became evident to Dr. Ricketts as the result of his work on spotted fever that the only method of controlling the disease was by destroying the natural agency of transmission. The work of the Bureau of Entomology in cooperation with the Montana Agricultural College and the Biological Survey in obtaining exact information about the life history and hosts of the tick has served to elaborate upon the suggestions made by Dr. Ricketts and to make it possible to lay down definite plans that should be followed.

It has been pointed out in this bulletin that the plan of eradication, which is dependent upon a knowledge of the tick, is entirely feasible and economical. The question now is whether the loss of 25 or more human lives per year in the Bitter Root Valley, the onus placed upon the development of the valley by the presence of spotted fever, and the danger of the spread of the virulent strain of spotted fever to other regions are not of sufficient importance to justify the small cost that the work will entail. A considerable portion of this cost would be offset by the improved condition of the live stock which would result from the destruction of the ticks as well as of certain other parasites.

CONDITIONS FAVORING CONTROL.

It will be understood from the discussion of the life history of the spotted-fever tick that several facts will assist greatly in an attack against it. Among these are the following:

(1) The vast majority of fever ticks which develop to the adult stage in the Bitter Root Valley do so upon horses and cattle, although small numbers develop upon sheep and a very few upon dogs. The only other domestic animal of any importance in the Bitter Root Valley is the hog. Although no fever ticks have ever been found upon hogs in the valley the adult form was taken in considerable numbers on that host on one occasion in Wyoming. It is therefore evident that under some conditions the hog is to be looked upon as an agency for the breeding of the ticks. The danger on this score, however, is exceedingly remote on account of the method of management of hogs in the valley. In the first place the number of these animals is not large. In the second place they are not allowed to roam at large but are confined to pens or small inclosures where the chances of their picking up fever ticks are very small. If hogs were

allowed to roam into the brushy land on the edges of the valley they might assume importance, but as the present plan of keeping them confined to areas where, for all practical purposes, ticks do not occur will undoubtedly be continued in the future, it is considered safe to ignore them in a plan of practical eradication.

(2) Aside from the domestic animals the wild species which have been found to carry the tick must be considered. These wild mammals can be divided for the purposes of this discussion into two groups, namely, those small forms which frequent the floor of the valley and extend in some cases to considerable elevations in the mountains, and the larger forms, like the bear, deer, elk, and mountain goat, which are more or less confined to the mountainous walls of the valley, but nevertheless sometimes visit the fields below.

Regarding the small wild mammals found throughout the valley, it was ascertained by examination of very large numbers of specimens that they seldom or never serve as hosts for the adult ticks. The immature forms of the fever tick are frequently to be found upon these mammals, but the *development of the adults is practically restricted to the larger domestic animals.*

Regarding the larger wild mammals it may be said that their numbers are rapidly decreasing. Some of them are practically extinct. The mountain goat, which appears more or less frequently to carry the adult fever tick, never invades the valley proper. In the winter it is to be found upon the lower rocks of the mountain walls, but it moves back to higher elevations as the snow melts. Therefore mountain goats tend rather to remove ticks from the valley than to plant them there. Among the other possible hosts, the two species of deer are rapidly becoming scarce. Moreover, in our investigations no fever ticks have been found attached to deer. The bear, among the wild mammals, is probably the most likely to serve as a host for the fever tick. It can not be considered that this mammal is abundant enough, however, to have any important bearing on the situation. The same is true of the coyote. In fact the number of ticks that could possibly be reared upon all the larger wild hosts would not be sufficient to cause any considerable infestation of the valley. These mammals can not be ignored altogether, but it is safe to consider them as comparatively unimportant. They might be of considerable importance if the project were to exterminate the fever in the valley and surrounding regions absolutely. But the plan here proposed is to reduce the cases of spotted fever to a practically negligible number in the valley. This is feasible and can be accomplished at small cost, while total eradication of the fever ticks in the mountains is not necessary to relieve the situation.

Since it has been pointed out that the larger domestic animals—horses, cattle, sheep, and dogs—are necessary hosts for the propaga-

tion of the fever tick, the problem of control becomes very greatly simplified. The immature stages may be allowed to develop on the small mammals in the valley so long as the adult stage may be destroyed upon the domestic animals which are necessary for its development.

Of course the reduction of the number of rodents in the valley, especially the Columbian ground squirrel, is advisable. These animals are more or less serious agricultural pests. They destroy a considerable amount of produce, and the inhabitants of the valley are in the habit of waging warfare against them. Undoubtedly the damage done is abundantly sufficient to warrant this work. The reduction of the rodents should be encouraged both on general economic principles and because they carry the immature stages of the spotted-fever tick. This line of work may well supplement the main work which must be done with the larger domestic animals, and will undoubtedly hasten the removal of the fever tick from the valley.

In one respect work against the rodents is of more than incidental value. It was found by Dr. Ricketts that five of these animals, namely, the gopher, rock squirrel, woodchuck, chipmunk, and mountain rat, are susceptible to spotted fever, and may serve as the original source of the disease in nature, or, at any rate, furnish a reservoir from which is derived the infection of human beings by the agency of ticks. The main point, however, is to destroy the tick which is necessary for the propagation of the disease, and this can be done by directing the principal efforts against the ticks on the larger animals which are under the control of man.

There are several facts, in addition to the practical restriction of the adult fever tick to the larger domestic animals, which will serve to render a campaign of eradication feasible. One of these is that the adult ticks are to be found on domestic animals or elsewhere during only a part of the year. Efforts toward eradication need not begin before March 1 and there would be no necessity for their continuance far beyond June 15. This is the season when the work can be done most easily and with smallest risk to the stock. A line of attack extending throughout the year is entirely unnecessary. Another favorable factor is the small number of live stock that would have to be treated. This is shown by the table below:

TABLE VII.—*Number of live stock in Bitter Root Valley. (U. S. Census, 1900.)*

	Ravalli County.	Missoula County.
Neat cattle	22,461	13,684
Horses	6,713	4,125
Mules	18	36
Sheep	58,212	4,942

Moreover, in the Bitter Root Valley eradication would not suffer the drawbacks connected with the ownership of large bodies of land by single persons which have attended similar work that has been undertaken in other parts of the country. The total number of farms in Ravalli County, as given in the census of 1900, was 891; their average size 199.4 acres. In Missoula County the same authority gives 615 farms of an average size of 241.6 acres.

An additional advantage will be found in the large proportion of farms in the county which are operated by their owners. Very little difficulty on account of nonresident ownership is to be expected. In Ravalli County 77 per cent of the farms are operated by the owners, and in Missoula County 89.

Aside from the specific factors which would operate to facilitate eradication of the spotted fever tick, others of a general nature may be mentioned, namely, the small size of the valley and its practical inclosure by high mountains, and the public interest in eradication which has already arisen. The Bitter Root Valley lies between high ranges of mountains over which there is practically no travel. The upper end of the valley is also closed by high mountains over which a very inconsiderable amount of traffic takes place. The lower end is narrowed almost to a gorge. Practically all the traffic into or out of the valley goes through this narrow opening at the northern end. The lay of the land gives an isolated region into which infection from the outside would be very unlikely to take place. For all practical purposes the guarding of the lower end for a portion of the year would be sufficient to prevent reinfection in case eradication is undertaken. The soil of the Bitter Root Valley has been found to be exceedingly fertile and especially adapted to certain profitable crops. It is recognized by all intelligent residents that the principal obstacle to the rapid development which has already begun is the occurrence of spotted fever. There is consequently a firmly embedded popular opinion that the destiny of the valley demands the eradication of the fever tick.

We may summarize the more important facts and conditions which would facilitate eradication of the fever tick as follows:

(1) Practical restriction of the adult stage of the tick to the larger domestic animals.

(2) The short season in the spring over which it would be necessary to carry on the principal work of eradication.

(3) The small number of animals that would have to be treated.

(4) The small size of the farms.

(5) The preponderance of resident farm owners.

(6) The isolation of the valley and the existence of effective natural barriers against reinfestation.

(7) A commendable public opinion in favor of removing an important obstacle to development.

IMPORTANCE OF CONTROL THROUGHOUT THE BITTER ROOT VALLEY.

For several reasons it is necessary to carry on this plan of eradication on both sides of the valley. It is known that the fever is very much less prevalent on the east than on the west side. This situation, however, is undoubtedly in part due to the heavier population on the west side and the greater number of live stock. There is every reason to believe that the settlement of the east side, with the inevitable increase in the number of live stock and, consequently, of opportunities for the ticks to breed to maturity, would result in an increased number of cases of spotted fever. That this is not a remote danger is shown by the fact that the development of the east side has already begun and will undoubtedly continue with rapidity. We do not wish to be understood as believing that the comparatively unsettled condition of the east side is the only reason for the scarcity of ticks. There are undoubtedly others. Among these is the greater abundance of rodent hosts for the immature stages of the tick on the west side. This is due primarily to the larger amount of protection in the brush or "slashings," although the settlement of the land and the planting of crops may have tended, by furnishing food, toward the multiplication of the rodents. Soil conditions may also have something to do with the difference.

The main point, however, is that the comparative immunity of the east side is not likely to continue. Destroying the ticks on both sides would cost but little more than on one. It would prevent the reinfestation of the west side. If it were not done, it would be necessary to establish and to maintain a quarantine against live stock on the east side. From every point of view it is wise to conduct a thorough work and clear both sides of the valley at the same time.

METHODS OF DESTROYING TICKS.

The two methods of eradicating ticks which will be found to be adapted to the conditions of the Bitter Root Valley are (1) the dipping of live stock in vats provided for the purpose, and (2) the hand treatment of such animals as can not conveniently be dipped.

In the case of the tick (*Margaropus annulatus* Say) which transmits splenetic fever of cattle, a third method has been found to be of great importance. This is the elimination of the ticks from pastures by "starving" them. This is accomplished by keeping the cattle out. During the warm portions of the year, at least, only a few months time without hosts will result in the death of the cattle ticks. Important differences between the life history of the splenetic-fever tick and that of the spotted-fever tick make that plan entirely impracticable in the case of the latter species. The problem of the splenetic-fever tick is not complicated by the existence of different hosts for the immature and the adult stages. That tick is absolutely depend-

ent upon cattle and remains on its host until mature. The spotted fever tick, however, drops to the ground twice for the purpose of molting and develops through the immature stages upon certain rodents and other animals. In the opinion of the Biological Survey the extermination of these rodents within reasonable time appears to be impracticable because of the necessary expense. The problem is even farther complicated by the remarkable ability of the fever ticks to live for long periods without hosts. As shown in the discussion of the longevity of the stages of the spotted fever tick, a period of three years, in which horses and cattle were kept out of the pastures, would be required before eradication could be brought about. This long period renders the so-called starvation plan entirely impracticable.

DIPPING.

Undoubtedly the so-called arsenical dip is the one best adapted for use in the Bitter Root Valley. In fact this dip has practically displaced all others for the destruction of ticks in various parts of the world. Crude oils have been used to a considerable extent in some cases. They are more expensive than the arsenical dip and dangerous to cattle under some conditions. Serious losses have followed the use of heavy oils in dry regions or where it has been necessary to drive the cattle any considerable distance after dipping.

Another advantage that the arsenical dip will be found to have over crude oil for the work in the Bitter Root Valley is that it will not act as a repellent. When cattle are oiled a portion of the oil remains in the hair and upon the skin for several days. This will prevent ticks from attaching. In the case of the arsenical dip, however, there is very little repellent effect. As the object of the work is to kill the ticks rather than to keep them from the animals, the more that can be caused to attach the better.

The formula for the arsenical dip is as follows:

Sodium carbonate (sal soda)	pounds	24
Arsenic trioxid (white arsenic)	do	8
Pine tar	gallons	2
Water to make	do	500

The preparation of the arsenical dip is described in Farmers' Bulletin No. 378, Methods of Exterminating the Texas-fever Tick, prepared by the Bureau of Animal Industry of this department, as follows:

In preparing the dip, a large caldron or galvanized tank is required for heating the water in which to dissolve the chemicals. Thirty or forty gallons of water should be placed in the caldron or tank and brought to a boil. The sodium carbonate is then added and dissolved by stirring. When this is accomplished, the arsenic is added and dissolved in a similar manner. The fire is then drawn and the pine tar added slowly in a thin stream and thoroughly mixed with the dip by constant stirring. This strong stock solution is diluted to make 500 gallons before using.

The only precautions necessary are to see that live stock are not allowed to drink it and to avoid heating the animals either before or after dipping. The dip can be used repeatedly until it becomes

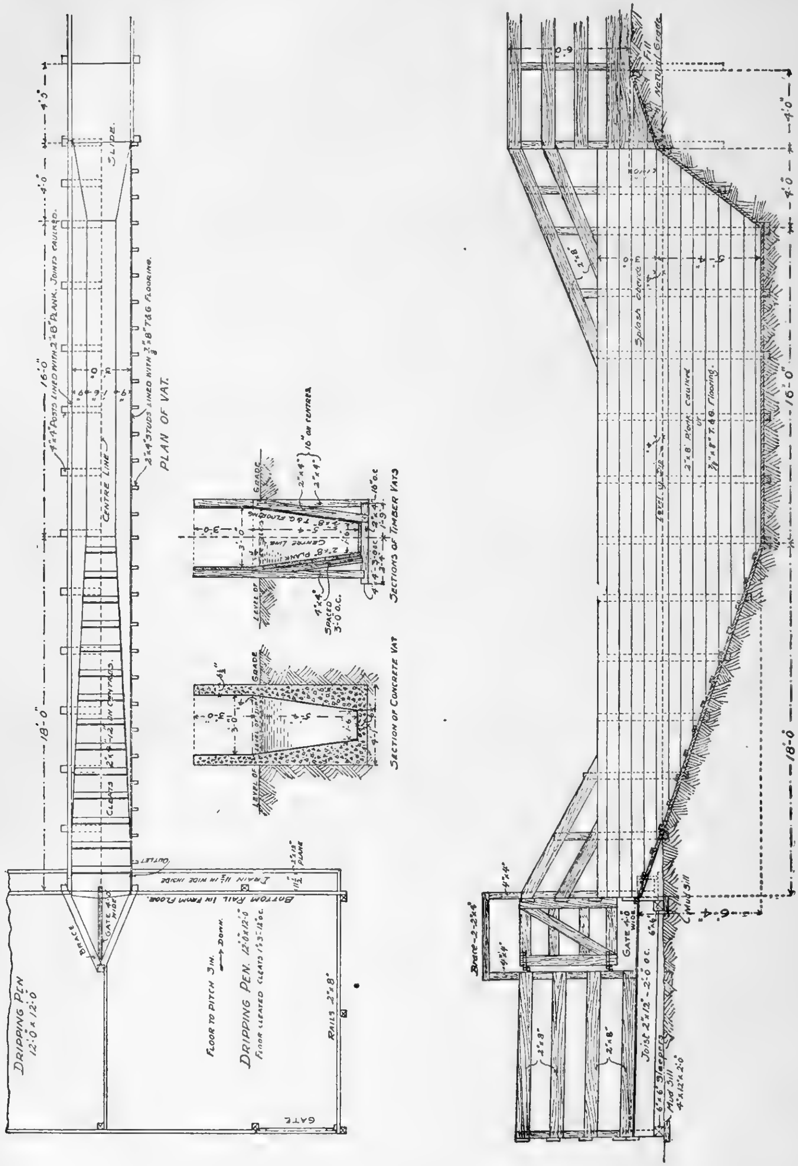


FIG. 3.—Drawings for wood or concrete dipping vat. (From Graybill, Farmers' Bulletin 378.)

befouled by foreign matter. A reasonable estimate of the cost of preparing this dip in the valley is $0.0031 per gallon, or $6.20 for an amount sufficient to fill a vat of 2,000 gallons capacity.

CONSTRUCTION OF VATS.

The specifications for such vats as will be found best adapted to use in Montana are taken from Farmers' Bulletin No. 378, already referred to, as follows:

SPECIFICATIONS AND MATERIALS FOR A DIPPING VAT.

A vat constructed according to the accompanying plans will hold 2,088 gallons when filled to a depth of 5 feet.

Excavation.—Excavate for the vat, as shown by the drawings [fig. 3], to the proper depth. Level the bottom of the pit for the sills. After the vat is completed fill in around it, using the surplus natural grade, and slope the surface away from the vat. Dig the holes required for all posts, etc.

Carpenter work.—The drawings show the vat constructed according to two methods. One method is to make the sides of 4 by 4 inch posts spaced about 3 feet apart and lined with 2 by 8 inch dressed, sized, and bevel-edged plank, using 20-penny spikes to fasten them to the posts and braces. All the joints are to be calked with oakum, well driven in with a calking iron, and pitched. The floor of the vat and the inclines are to be made of 2-inch plank, with joints calked; the exit incline to have 2 by 4 inch cleats spiked to the plank flooring. The slide should have an angle of about 25° and should be covered with No. 16 galvanized iron.

The other method is to build the sides of the vat of 2 by 4 inch posts and 2 by 4 inch braces spaced about 16 inches on centers. The 2 by 4 inch posts and braces are to be lined with $\frac{7}{8}$ by 8 inch tongued-and-grooved flooring, blind nailed at every bearing with 10-penny nails. All the joints are to be laid in white-lead paste and the boards firmly driven up.

Lumber.—The lumber used in the construction of the vat must be thoroughly dried and seasoned stock, free from large and loose knots, straight grained, and free from sap.

Gutters.—The gutters for the dripping pens should be made of sound stock, the bottom plank housed into the sides and ends, and the ends housed into the sides. All the joints are to be laid in white-lead paste and thoroughly nailed. Gutters are to have a 3-inch fall in 11 feet.

Bill of materials for vat and draining pens.

Vat:

- Sills, 8 pieces 4 by 4 inches by 10 feet long.
- Posts—
  - 1 piece 4 by 4 inches by 16 feet long.
  - 1 piece 4 by 4 inches by 14 feet long.
  - 6 pieces 4 by 4 inches by 12 feet long.
  - 5 pieces 4 by 4 inches by 10 feet long.
- Braces—
  - 1 piece 4 by 4 inches by 16 feet long.
  - 6 pieces 4 by 4 inches by 12 feet long.
  - 1 piece 4 by 4 inches by 10 feet long.
  - 1 piece 4 by 4 inches by 6 feet long.
- Guards—
  - 2 pieces 2 by 8 inches by 18 feet long.
  - 1 piece 2 by 8 inches by 16 feet long.
  - 2 pieces 2 by 8 inches by 12 feet long.
  - 1 piece 2 by 8 inches by 10 feet long.

Vat—Continued.

Sides—

18 pieces 2 by 8 inches by 20 feet long.

25 pieces 2 by 8 inches by 18 feet long.

2 pieces 2 by 8 inches by 16 feet long.

2 pieces 2 by 6 inches by 18 feet long.

Dressed one side and two edges.

Edges beveled for calking.

Floor—

3 pieces 2 by 10 inches by 20 feet long.

2 pieces 2 by 10 inches by 16 feet long.

1 piece 2 by 10 inches by 14 feet long.

1 piece 2 by 10 inches by 7 feet long.

1 piece 2 by 12 inches by 12 feet long.

Dressed one side and two edges.

Edges beveled for calking.

Cleats, 4 pieces 2 by 4 inches by 12 feet long.

Lumber for draining pens:

Mud sills, 10 pieces 4 by 12 inches by 2 feet long (cedar or cypress).

Sleepers, 4 pieces 6 by 6 inches by 12 feet long.

Joists, 13 pieces 2 by 12 inches by 12 feet long.

Floor, 360 feet b. m. tongue-and-groove flooring $\frac{7}{8}$ by 8 inches, 12-foot pieces.

Cleats, 265 linear feet 1 by 3 inches.

Gutters—

Sides, 4 pieces 2 by 12 inches by 11 feet long (dressed).

Bottom and ends, 2 pieces 2 by 12 inches by 12 feet (dressed).

Bottom housed into side and ends. Ends housed into sides. All joints calked and white leaded or pitched.

Posts—

11 pieces 4 by 4 inches by 7 feet long.

2 pieces 4 by 4 inches by 8 feet long.

2 pieces 4 by 4 inches by 9 feet long.

Rails—

2 pieces 2 by 8 inches by 18 feet long.

5 pieces 2 by 8 inches by 16 feet long.

18 pieces 2 by 8 inches by 12 feet long.

Braces, 2 pieces 2 by 4 inches by 10 feet long.

Gates—

7 pieces 1 by 6 inches by 12 feet long.

6 pieces 1 by 6 inches by 10 feet long.

Hardware for vat and draining pens:

4 pairs 12-inch heavy T hinges and screws.

4 wrought-iron hooks and staples.

1 pair wrought-iron hook hinges, 12-inch, wood screw hooks, and screws.

50 pounds 20-penny wire nails.

15 pounds 10-penny wire nails.

12 square feet No. 16 galvanized iron.

The vat described is of the proper depth for cattle and horses. For sheep a platform should be provided which will rest on legs long enough to bring this platform 4 feet below the surface of the dip. This can be easily made so that it can be removed or replaced in a

few minutes to allow, if necessary, for the alternate dipping of cattle and sheep.

In selecting a site for the construction of the vat the desirability of having the ground slope away from it on one side should be kept in mind. This allows for the draining of the vat through a pipe inserted at its bottom. This drain should lead to a basin, preferably on waste land. Care should be exercised to prevent animals from drinking from the pool into which the old dip is drained and also to prevent the dip from being washed into streams used for domestic purposes.

In order to prevent the dip from becoming diluted by rains and to check evaporation, a roof of boards or canvas over the vat is desirable.

HANDWORK IN THE DESTRUCTION OF THE SPOTTED-FEVER TICK.

For the most part the use of dipping vats will furnish all facilities necessary for the eradication of the ticks. However, in certain cases, as, for instance, in the narrow valleys running some distance into the mountains, the expense of constructing dipping vats for the small number of cattle present would be prohibitive. Instead of driving these cattle considerable distances to dipping vats, it will be found sufficient to treat them thoroughly by hand methods. The procedure is simply to apply the arsenical dipping mixture liberally by means of rags, mops, or brushes, or by means of spray pumps. It may be found advisable in some cases to use oil instead of the dip, although the main reliance should be placed upon the use of the dip. Oil from Wyoming, which will be found perfectly adapted to this use, can be obtained in the Bitter Root Valley, when purchased in large quantities, at a cost of about $1.25 per barrel.

DEFINITE RECOMMENDATIONS FOR CONTROL OR ERADICATION OF THE SPOTTED-FEVER TICK IN THE BITTER ROOT VALLEY.

The following are the steps that should be followed for the control or eradication of the spotted-fever tick in the Bitter Root Valley:

(1) A campaign of education whereby all the residents of the valley will be made thoroughly familiar with the feasibility of the plan of eradication and with what it will mean in the development of the valley.

(2) The obtaining of legislation to make it possible to dip or oil all live stock in the Bitter Root Valley. In general, public opinion would be sufficient to bring about the treatment of a large majority of the animals. In a few cases objections would undoubtedly be raised by farmers. Without the treatment of all live stock, the plan would necessarily fail. For this reason it is absolutely essential to

provide such legislation as will make it possible to enforce the treatment of all the animals.

(3) The obtaining of an accurate census of the horses, cattle, sheep, mules, and dogs in the valley.

(4) The construction of 10 or more dipping vats.

(5) The providing of materials to be used in the dipping mixture.

(6) The organization of a corps of workers to carry on the operations.

(7) The systematic dipping of the horses, cattle, sheep, and dogs of the valley on a definite schedule. The time of beginning and of discontinuing this work will depend somewhat upon the seasons, but should be about as indicated below. Weekly dippings are necessary, because, as pointed out in the discussion of the life history of the tick, adults may attach to domestic animals, engorge, and drop to the ground in a minimum of eight days:

March 10.
March 17.
March 24.
March 31. (Vat refilled on this date.)
April 7.
April 14.
April 21. (Vat refilled on this date.)
April 28.
May 5.
May 12.
May 19. (Vat refilled on this date.)
May 26.
June 2.
June 9.

(8) The treatment by hand of the animals in localities remote from vats should be undertaken on this same schedule.

One season's work would certainly result in a very large reduction in the number of fever ticks present in the valley. The second season's operations would bring about still further reduction in numbers, if not practical eradication. Nevertheless, a third season's work is required to make certain of the results.

ESTIMATED EXPENSES OF PRACTICAL ERADICATION OF SPOTTED-FEVER TICK IN THE BITTER ROOT VALLEY, MONT., NOT INCLUDING THE COST OF EXPERT SUPERVISION AND NECESSARY INVESTIGATION.

The approximate cost of the work for the three seasons is indicated in the statement given herewith, which does not, however, include the cost of such expert supervision and additional investigation as are required.

First year:	
10 vats, costing $200 each	$2,000
Each vat to have a capacity of 2,000 gallons.	
Cost of filling vats four times during season, at $0.0031 per gallon.[1]	248
Salary of one superintendent, 12 months	1,800
Salaries of 10 assistants for 5 months, at $80 each	4,000
The period to be covered by these men extends from Feb. 15 to July 15.	
Incidentals	1,000
Total, first year	9,048
Second year:	
Repairs to vats	200
Cost of filling vats four times during season	248
Salary of one superintendent	1,800
Salaries of 10 assistants	4,000
Incidentals	1,000
Total, second year	7,248
Third year:	
Repairs to vats	300
Cost of filling vats four times	248
Salary of one superintendent	1,800
Salaries of 10 assistants	4,000
Incidentals	1,000
Total, third year	7,348
Grand total	23,692

It may be found that more than 10 vats will be required. In that case the output for materials would be increased somewhat.

After three seasons' operations a very small annual expenditure will be necessary to avoid reinfestation of the valley by the incoming of cattle from other places. This could be easily accomplished by employing an inspector at a salary of, say, $100 per month for six months' service each year.

SUPPLEMENTARY MEANS OF CONTROL.

The main reliance in work of controlling the spotted-fever tick must be placed upon the dipping and hand treatment of domestic animals. However, there are certain supplementary means of control which should be practiced. These are (1) the reduction in the number of rodents in the valley and (2) the clearing of the brush land along the edges of the valley.

As has been explained in this bulletin, the destruction of the rodents is not a vital part of the plan of eradication we propose.

[1] The cost of dip per gallon is computed as follows: Arsenate trioxide, 5½ cents per pound; sodium carbonate, 2 cents per pound; tar, 33⅓ cents per gallon.

Nevertheless, if the number of these animals can be reduced, it will have an important effect in lessening the number of ticks present. In addition to this reason for control, the rodents are pests of considerable importance. Their extermination from the valley, if possible, would amply repay the residents in the preventing of losses to their crops.

The conditions existing in the brushy land or "slashings" along the edge of the valley are especially favorable to the tick. Not only is shade and protection furnished, but the presence of the timber furnishes the rodent hosts favorable opportunities for multiplication. In this way the presence of the brush has an important bearing upon the abundance of ticks. If the land should be cleared, the ticks would be considerably affected. Clearing the lands will, of course, increase their value and make possible their planting in orchards or other crops without loss of time when the fever tick shall have come under subjection.

For a full list of the mammals found in and around the valley and for methods for their extermination the reader is referred to Circular 82 of the Biological Survey of this department.

It is not considered necessary to have these supplementary means of control supported by funds raised for the main operations. The work of destroying rodents and of clearing the brush lands should be conducted by residents on their own initiative. The matter should be sufficiently explained and the residents should by every means possible be encouraged to undertake the work.

NECESSITY FOR EXPERT SUPERVISION.

In the work of controlling the spotted-fever tick in the Bitter Root Valley it is absolutely essential that expert entomological supervision be provided. Since the whole campaign depends upon a knowledge of the habits and life history of ticks it must be evident that the work must be in the hands of persons who are thoroughly familiar with the subject. Among the many reasons why this expert supervision is necessary are—

(1) The proper time to begin and to discontinue the dipping or oiling must be determined. This will depend upon the seasons and the time when the tick begins to develop in the spring. Unless men are at hand to determine when to begin and when to end, much unnecessary work might be done or, what is worse, many ticks might escape.

(2) It is necessary to be certain that the dipping solution is kept up to a strength sufficient to kill and to see that the dipping is properly done. The test of the strength of the solution should be conducted by experiments the results of which could be interpreted safely only by experts.

(3) The campaign of education which should be conducted in connection with the other work can only be carried on effectively by persons who by training and experience know thoroughly the points upon which the system is based. The best work can only be done by those who have had experience in similar problems and who are familiar with data sufficient to refute such fallacious arguments as may be adduced from time to time.

(4) It is possible that means of control additional to those enumerated in this bulletin may be discovered. The chance of such discoveries and the consequent hastening of the work will be increased if persons trained in entomological work are in charge.

BIBLIOGRAPHY OF THE MORE IMPORTANT WRITINGS ON THE SPOTTED-FEVER TICK.

1903. ANDERSON, J. F.
Spotted fever (tick fever) of the Rocky Mountains. A new disease. <Bul. 14, Hygienic Laboratory, U. S. Public Health and Marine-Hospital Service, pp. 50, pls. 1–3.

1905. STILES, CH. WARDELL.
A zoological investigation into the cause, transmission, and source of Rocky Mountain "spotted fever." <Bul. 20, Hygienic Laboratory, U. S. Public Health and Marine-Hospital Service, pp. 121.
A valuable bibliography is included.

1906. RICKETTS, H. T.
The study of "Rocky Mountain spotted fever" (tick fever?) by means of animal inoculations. A preliminary communication. <Journ. Amer. Med. Assn., vol. 47, no. 1, pp. 33–36.

1906. KING, W. W.
Experimental transmission of Rocky Mountain spotted fever by means of the tick. Preliminary note. <Public Health Reports, U. S. Public Health and Marine-Hospital Service, vol. 21, no. 30, pp. 863–864, July 27.

1906. RICKETTS, H. T.
The transmission of Rocky Mountain spotted fever by the bite of the wood tick (*Dermacentor occidentalis*). <Journ. Amer. Med. Assn., vol. 47, no. 5, p. 358, August 4.

1906. RICKETTS, H. T.
Further observations on Rocky Mountain spotted fever and *Dermacentor occidentalis*. <Journ. Amer. Med. Assn., vol. 47, no. 14, pp. 1067–1069, October 6.

1907. RICKETTS, H. T.
Observations on the virus and means of transmission of Rocky Mountain spotted fever. <Journ. Infectious Diseases, vol. 4, no. 1, pp. 141–153.

1907. RICKETTS, H. T.
The rôle of the wood tick (*Dermacentor occidentalis*) in Rocky Mountain spotted fever and the susceptibility of local animals to this disease. A preliminary report. <Journ. Amer. Med. Assn., vol. 49, pp. 24–27.

1907. RICKETTS, H. T.
Further experiments with the wood tick in relation to Rocky Mountain spotted fever. <Journ. Amer. Med. Assn., vol. 49, pp. 1278–1281.

1908. MAXEY, E. E.
Rocky Mountain spotted (tick) fever with special reference to casual factors, mortality, and geographical distribution in Idaho. <Medical Sentinel, Portland, Oreg., December.

1908. STEWART, J. L., and W. F. SMITH.
Clinical phases of Rocky Mountain spotted fever. <Medical Sentinel, Portland, Oreg., December.

1908. RICKETTS, H. T.
Recent studies of Rocky Mountain spotted fever in Montana and Idaho. <Medical Sentinel, Portland, Oreg., December.

1908. TUTTLE, T. D.
Some indications for State control of Rocky Mountain tick fever. <Medical Sentinel, Portland, Oreg., December.

The four preceding papers were republished by the Medical Sentinel with continuous pagination under the title " Symposium on Rocky Mountain Tick Fever."

1908. BANKS, NATHAN.
A revision of the Ixodoidea or ticks of the United States. <Tech. Ser. 15, Bur. Ent., U. S. Dept. Agr., pp. 1–61, pls. 1–10.

1908. SMITH, W. F. (See STEWART, J. L.)

1909. RICKETTS, H. T.
A microorganism which apparently has a specific relationship to Rocky Mountain spotted fever. A preliminary report. <Journ. Amer. Med. Assn., vol. 52, no. 5, pp. 379–380.

1909. RICKETTS, H. T.
Spotted Fever Report No. 1. General report of an investigation of Rocky Mountain spotted fever, carried on during 1906–7. <4th Bien. Rept. State Board Health Montana, pp. 87–130.

1909. RICKETTS, H. T.
Spotted Fever Report No. 2. A report of investigations carried on during the winter of 1907–8 and the spring and summer of 1908. <4th Bien. Rept. State Board Health Montana, pp. 131–191.

The two papers above constitute the most detailed and comprehensive of Dr. Ricketts's various reports on his investigations in Montana.

1909. COOLEY, R. A.
Preliminary report on the wood tick. <6th Ann. Rept. Mont. Agr. Exp. Sta., pp. 95–104, 1 plate, 1 fig.

This paper was also published as Bulletin 75 of the Montana Agricultural Experiment Station, together with the following:

1909. COOLEY, R. A.
Account of trip into West Gallatin Canyon to study ticks. <Bul. 75, Mont. Agr. Exp. Sta., pp. 105–108.

1910. STILES, CH. WARDELL.
The taxonomic value of the microscopic structure of the stigmal plates in the tick genus Dermacentor. <Bul. 62, Hygienic Laboratory, U. S. Public Health and Marine-Hospital Service, pp. 72, pls. 43.

1911. BISHOPP, F. C.
The distribution of the Rocky Mountain spotted-fever tick. <Cir. 136, Bur. Ent., U. S. Dept. Agr., pp. 1–4, 1 fig.

1911. TUTTLE, T. D.
Rocky Mountain spotted (tick) fever. <5th Bien. Rept. State Board Health Montana, pp. 9–12.

1911. MAVER, MARIA B.
Transmission of spotted fever by other than Montana and Idaho ticks. <Journ. Infectious Diseases, vol. 8, no. 3, pp. 322–326.

1911. Maver, Maria B.
Transmission of spotted fever by the tick in nature. <Journ. Infectious Diseases, vol. 8, no. 3, pp. 327–329.

1911. Moore, Josiah J.
Time relationships of the wood-tick in the transmission of Rocky Mountain spotted fever. <Journ. Infectious Diseases, vol. 8, no. 3, pp. 339–347.

1911. Cooley, R. A.
Tick control in relation to the Rocky Mountain spotted fever. A report of cooperative investigations conducted by the Bureau of Entomology and the Montana Experiment Station. <Bul. 85, Mont. Agr. Exp. Sta., pp. 1–29.

1911. Hunter, W. D., and Bishopp, F. C.
Some of the more important ticks of the United States. <Yearbook, U. S. Dept. Agr. for 1910, pp. 219–230, 2 pls.

1911. Henshaw, Henry W., and Birdseye, Clarence.
The Mammals of Bitter Root Valley, Montana, in their relation to spotted fever. <Cir. 82, Bur. Biol. Survey, U. S. Dept. Agr., pp. 1–24, 12 figs.

The important papers of Dr. Ricketts have recently (May, 1911) been reprinted by the University of Chicago Press in a memorial volume entitled "Contributions to Medical Science."